REF. LIBRARY

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1954

LONDON
HER MAJESTY'S STATIONERY OFFICE
1955

Addresses of Principal Research Offices of the Forestry Commission

Director of Research and Education:
25 Savile Row, London W.1. (Regent 0221)

Chief Research Officer:
Alice Holt Research Station,
Wrecclesham, Farnham, Surrey (Bentley 2255)

Silviculturist, Scotland and North England:
Forestry Commission,
Government Building, Bankhead Avenue, Sighthill, Edinburgh 11
(Craiglockhart 4010)

CONTENTS

PART III: REPORTS ON RESULTS OF INDIVIDUAL INVESTIGATIONS

APPENDICES

INTRODUCTION

By JAMES MACDONALD

Director of Research and Education

THE form of this report differs in some particulars from that of preceding reports. The first section consists of brief summaries of the main items of work which are proceeding in the Research Branch of the Forestry Commission; the second gives reports on various projects which are under investigation by Universities and other Institutions; the third, which is new, comprises a series of papers by various members of the research staff on subjects which have yielded sufficient information to be made public in this form, although, here and there, the information given must be regarded as provisional. We have also added a list of the more important experimental areas in Great Britain, classified under subjects; this may help those who are unfamiliar with the stations at which most of the experimental work is being conducted.

The Late Dr. E. M. Crowther

The sudden death of Dr. E. M. Crowther of Rothamsted, early in 1954, was a great loss to forest research for in recent years he had given much of his time to the study of the complex problems of the nutrition of young trees in the nursery.

Since 1944, when the Advisory Committee on Forest Research set up a sub-Committee to study nursery nutrition, Crowther had played the leading part in the planning and execution of the ambitious programme of research which followed, and much of the success which has been achieved is due to the energy and enthusiasm which he never failed to show. It is regretted that he was not spared to write an account of this important work himself; but this is now being undertaken by Miss Blanche Benzian who was closely associated with him in the work of the sub-Committee.

Staff and Accommodation

There have been few changes in the staff. Mr. R. D. Pinchin, District Officer, left the Research Branch on transfer to the Welsh Directorate; Mr. J. R. Aldhous was appointed District Officer and posted to the silviculture section under Mr. R. F. Wood.

Substantial progress was made with the building of eight new houses at Alice Holt, to accommodate foresters and foremen on the staff. Additional accommodation was provided for the entomologist in the form of a new building for the breeding of insects.

Visits

During the year, the Research Station at Alice Holt was visited by a party of Members of Parliament, by members of the Royal Forestry Society of England and Wales, and by students from the Imperial College, London, and from the Universities of Oxford, Aberdeen and Wales. The other visitors included people from Australia, Argentina, Bolivia, Burma, Canada, Chile, Cyprus, Denmark, Germany, India, Ireland, Israel, Japan, New Zealand, Norway, Pakistan, Rhodesia, Siam, Spain, Uganda and the United States of America. In all there were 252 visitors to Alice Holt, about the same number as last year.

Visits to experimental areas in different parts of the country were arranged for forest officers from Norway, Denmark, Germany, Rhodesia, Australia and Bolivia.

The Director, with Messrs. M. V. Laurie, M. V. Edwards and G. D. Holmes, attended the eleventh Congress of the International Union of Forest Research Organisations in Rome in September 1953.

Mr. Holmes took part in the tenth Convention of the International Seed Testing Association which was held in Dublin in May 1953 and, with Mr. Laurie, he attended the National Weed Control Conference at Margate in November of that year.

At the invitation of the Cyprus Government, Dr. F. C. Hummel visited Cyprus from December 1953 to March 1954, in order to advise on certain problems of forest management.

Advisory Committee on Forest Research

The Advisory Committee on Forest Research held their summer meeting at Drumnadrochit in Inverness-shire and were able to inspect one of the principal experimental areas, the Lon Mor, at Inchnacardoch Forest near Fort Augustus, where the establishment of plantations on difficult peat has been studied for a quarter of a century. They also saw some of the other work in the district. The Committee held a second meeting in London in December 1953. The Advisory Committee, at the end of the year under review, was composed of the following members:

Professor John Walton, *Forestry Commissioner*, *Chairman*
Professor H. G. Champion, C.I.E.
Dr. J. W. Gregor
Dr. W. J. Hall, C.M.G.
Dr. F. Y. Henderson, C.B.E.
Mr. G. V. Jacks
Sir William G. Ogg
Sir E. J. Salisbury, C.B.E., F.R.S.
Professor H. M. Steven
Sir William Wright Smith, F.R.S.
Mr. M. V. Laurie, O.B.E., *Secretary*

Sub-Committee on Nursery Nutrition

The sub-Committee on Nursery Nutrition held meetings during the year and carried out a heavy programme of experimental work but, unfortunately, it became necessary to consider the re-arrangement of the sub-Committee's activities as a result of the death of Dr. E. M. Crowther. The sub-Committee consisted of the following members at the end of the year:

Professor Steven (*Chairman*)
Mr. G. V. Jacks
Professor A. B. Stewart, Aberdeen University
Dr. Ida Levisohn, Bedford College, London
Dr. S. D. Garrett, Cambridge University

Liaison with Other Research Organisations

Close contact has been maintained with Universities and Institutions engaged in research in forestry and in related subjects, and in this connection mention must be made specially of Rothamsted Experimental Station, The Macaulay Institute for Soil Research, The Imperial Forestry Institute and the Forest Products Research Laboratory. To the various Professors and to the Directors of these Institutes we are deeply indebted for the help they have given. The Nature Conservancy, which is concerned with woodlands, has also been of great assistance to our research officers. In order to secure good liaison in fields of common interest, a small informal Committee has been established, consisting of representatives of the Nature Conservancy and of the Commission, to discuss matters of research and investigation. The Commission's Research Branch has continued to take an active part in the affairs of the International Union of Forest Research Organisations, the Director serving as a member of the Permanent Committee. The Union proposes to hold its twelfth Congress in Great Britain in 1956.

Part I. Summary Reports on Work carried out by Forestry Commission Staff.

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES, *Assistant Silviculturist* and
G. BUSZEWICZ, *Experimental Officer*

ROUTINE testing of the purity and germination quality of the Commission's seed continued as the main function of the Seed Testing Laboratory at Alice Holt and, as in previous years, research on seed problems took second place. 1,066 germination tests were completed on seed samples received, including 862 using laboratory germinators and 204 rapid viability tests using the tetrazolium staining technique. In addition 58 tests of seed moisture content were completed. The majority of routine germination tests were made on Copenhagen tank germinators, of which there are now 25 in the laboratory. All the routine tests were completed during the seven months from October to April, and all available germinators were in full operation throughout this period. The seed pre-chilling technique described in *Rep. For. Res. Year Ending March* 1953, has been adopted as a standard treatment for seed samples of Douglas fir, Sitka spruce and *Pinus contorta* to accelerate the rate of germination in the laboratory. This pre-treatment has permitted a greater number of tests to be completed in the year than would have been possible otherwise with available equipment. The tetrazolium rapid viability test has been applied only to late-arriving samples on which a quick report was essential. In all cases the results were checked by standard germination test methods.

Germination Test Methods

Biochemical Methods

The examination of triphenyl tetrazolium bromide as a chemical indicator of seed viability for rapid estimation of seed germination quality, was continued into its fifth year. This extensive investigation has covered seven common conifer species with the object of assessing the relationships between the results of tetrazolium viability tests, standard germinator tests, and field germination, over a wide range of conditions. The collected data for the five year period is now under analysis. Tetrazolium has proved a satisfactory viability indicator for the majority of conifer species, and gives results comparable with those from standard germinator methods. The amount of time and skill required in seed cutting and embryo extraction and classification is a disadvantage of the tetrazolium method, but it is undoubtedly of great value for application to those samples on which a result is required urgently, as a test can be completed in twelve hours. The technique has been found most valuable for testing species such as *Pinus peuce* and hardwoods such as ash, lime and *Prunus* species, which have dormant seeds and are difficult to test by other methods without prolonged pre-treatment.

Improvement of Test Methods for Slow Germinating Species

Many tree species have seeds which germinate very slowly even under ideal conditions, and seed of several species require pre-treatment before they will germinate at all. This presents a serious problem to the seed analyst who is concerned with completing germination tests in the shortest possible period of time, and in 1953 several experiments were carried out on this problem.

Sitka spruce, Douglas fir and Pinus contorta

These species have been found to exhibit varying degrees of dormancy; some samples germinate normally within 28 days on a germinator, while frequently others require up to 70 days for complete germination.

Investigation of methods of seed pre-treatment and germination test for these species confirmed that pre-chilling the seeds for 14 to 21 days under moist conditions at 36°F. accelerates the rate of germination, and allows completion of the germination test in the laboratory within 14 days. The Copenhagen tank germinator operated at an alternating temperature of 68 to 86°F. has proved the most satisfactory germination method.

Acer saccharum

This species is not commonly used in this country, but difficulty has been experienced in testing the small number of seed samples which have been received. The seed is dormant, and laboratory tests in sand, between blotters, or on paper on the Copenhagen tank, have shown no germination after 120 days. It was found necessary to pre-chill the seeds on wet blotters for at least 8 weeks to obtain rapid germination. With this pre-treatment germination was completed in 14 days at 68 to 82.4°F. Application of the tetrazolium method to seeds without pre-treatment has given satisfactory results for the small number of samples examined.

Tilia species

Lime has proved most difficult to test by normal methods as it shows so called "double dormancy" caused by an impermeable pericarp and testa, and an embryo which requires some period under favourable conditions for ripening. Experiments showed that mechanical removal of the pericarp and scarification of the testa, or softening the testa by means of nitric or sulphuric acid, were ineffective, unless followed by a minimum of 6 months moist stratification to condition the embryo. So far, pre-chilling has not been successful.

Nothofagus procera and N. obliqua

There is no established routine method for testing seeds of these species. Trials in 1953 indicate that the two species exhibit different degrees of dormancy, *Nothofagus obliqua* being the more dormant species. *N. obliqua* showed negligible germination in the laboratory after 35 days, but seed pre-chilled for 21 days prior to setting up the test gave almost full germination within 35 days at an alternating temperature of 68 to 82.4°F. *N. procera* germinated satisfactorily without pre-treatment. Evidence from nursery sowing trials indicate that satisfactory germination can be ensured by stratification of *N. obliqua* for two months and *N. procera* for one month prior to sowing.

Seed-borne Fungi

Dr. S. Batko continued his work in recording the occurrence of fungi developing on seeds during the course of germination tests.

The previous year's list has been enlarged by recording the following fungi: *Chaetomium indicum*, *Camarosporium* sp., *Melanospora* sp., *Mucor racemosus*, *Pachybasium* sp., and *Pestalozzia funerea*.

A rare fungus, very little known in this country, has also been recorded: *Memnoniella echinata*. More *Fusaria* have been identified. Species of the difficult genus *Penicillium* still await further identification, and various species of, it may be, different virulence.

Some records of the fungi are given below:

Fungus	Tree Seeds affected
Ascophanus carneus	*Pseudotsuga taxifolia*, *Pinus laricio* var. *calabrica*, *Pinus sylvestris*, *Picea sitchensis*.
Aspergillus niger	*Robinia pseudoacacia*, *Libocedrus decurrens*, *Pinus laricio* var. *calabrica*, *Larix leptolepis*.
Alternaria tenuis	*Pinus sylvestris*, *Picea sitchensis*, *Pseudotsuga taxifolia*, *Sarothamnus scoparius*, *Pinus flexilis*, *Tsuga heterophylla*, *Larix decidua*, *Nothofagus obliqua*.
Botrytis cinerea	*Pinus sylvestris*, *Nothofagus obliqua*, *Acacia dealbata*, *Acacia riceana*, *Cupressus macrocarpa*.
Chaetomium globosum	*Pinus laricio* var. *calabrica*, *Pinus sylvestris*, *Pinus radiata*. Common on blotting paper.
Cylindrocarpon sp.	*Pseudotsuga taxifolia*, *Castanea sativa* and *Aesculus hipposcastanum*.
Epicoccum purpurascens	*Picea sitchensis*, *Pinus laricio* var. *calabrica*, *Larix decidua*, *Pinus pinaster*, *Nothofagus obliqua*.
Fusarium sambucinum	*Pinus pinaster*
Fusarium oxysporum aurantiacum	*Thuja plicata*
Fusarium oxysporum	*Tsuga heterophylla*
Fusarium bulbigenum blasticola	*Pinus radiata*, *Larix decidua*, *Thuja plicata*.
Memnoniella echinata	*Picea sitchensis*, *Larix leptolepis*
Oedocephalum glomerulosum	*Pseudotsuga taxifolia*, *Pinus laricio* var. *calabrica*, *Picea sitchensis*, *Larix leptolepis*.
Pestalozzia funerea	*Pseudotsuga taxifolia*, *Libocedrus decurrens*, *Pinus pinaster*.
Rhizopus nigricans	*Thuja plicata*, *Picea sitchensis*, *Pseudotsuga taxifolia*, *Pinus flexilis*, *Abies concolor*, *Tsuga heterophylla*, *Cupressus macrocarpa*, *Libocedrus decurrens*.
Stysanus	*Picea sitchensis*, *Pinus contorta*.
Stemphylium	*Pinus sylvestris*, *Thuja plicata*, *Pinus pinaster*, *Chamaecyparis lawsoniana*.
Stachybotrys atra	*Picea sitchensis*, *Lupinus* sp., *Robinia pseudoacacia*, *Pinus sylvestris*, *Pinus laricio* var. *calabrica*, *Sarothamnus scoparius*. Common on blotting paper.
Penicillium spp.	Common on all seeds especially on *Abies* sp. Possibly several species which may vary in virulence.
Verticillium spp.	*Picea sitchensis*, *Pseudotsuga taxifolia*, *Tsuga heterophylla*.

Many of these fungi which have now been isolated in pure culture are probably saprophytic, but as yet tests have not been made to assess the effect of these species on seed germination and seedling development. The next step in evaluation of the effects of these fungi will be to carry out inoculation trials on surface sterilised seed.

Estimation of Seed Quality from Cone Samples taken Prior to Bulk Collection

During the year, sixty samples of cones sent in from Conservancies were examined and reports issued. An attempt has been made to work out a satisfactory quick method of estimating the sound seed content of cones by examination of the cut surfaces of the cones after cutting in half longitudinally. It is possible to make an approximate estimation of the yield of sound seeds by this means and efforts are being made to assess the reliability of the quick method by examination of a large number of samples. A special knife has been designed for longitudinal sectioning of cones, and it is hoped that this may soon be available for forest use.

Seed Storage

An investigation into the longevity of acorns stored under a variety of conditions was started in autumn 1950, and the results after two years were reported in *Rep. For. Res. Year Ending March* 1953. Examination of samples three years after placing the seeds in store showed that storage of acorns in air dry granulated peat at a constant temperature of 36°F. was the best method. Germination tests on samples showed only a small drop in seed germination capacity over the three years, although the speed of germination, or germination energy, was considerably reduced.

In long-term storage experiments with seed of common conifer species, storage of seed dried to just below 10 per cent on dry weight, in sealed containers kept at 36°F., continued to give good results after four years. Similarly, it has been shown that birch can be stored satisfactorily for at least four years under these conditions.

Other Activities

During the year the opportunity was provided to take part in the 10th Convention of the International Seed Testing Association held at Dublin in May, 1953. At this meeting, revised International Rules for Seed Testing, including sections relating to forest tree seeds, were agreed. The new International Rules relating to tree seeds were later ratified by the 11th Congress of the International Union of Forest Research Organisations in Rome. The Seed Testing Laboratory at Alice Holt has now undertaken a series of experimental seed tests in collaboration with the Biochemical and Forest Tree Seed Committees of the I.S.T.A.

EXPERIMENTAL WORK IN NURSERIES

By G. D. HOLMES, *Assistant Silviculturist* (South) and

R. FAULKNER, *Assistant Silviculturist* (North)

Partial Sterilisation of the Soil

Trials of Formalin as a Partial Sterilising Agent

As mentioned in the *Report on Forest Research for year ending March* 1953, a series of "user-scale" trials of formalin were carried out in 1952 in a number of Conservancy nurseries, using a technique and application rate of formalin, which had proved satisfactory in previous experiments. The object was to assess the effects of formalin on seedling growth on as wide a variety of nursery soils as possible, as a preliminary to recommendations for adoption of the treatment on a larger scale.

The 1952 trials gave most disappointing results, as only three out of the ten nurseries examined showed improved seedling growth following formalin treatment. It was not possible to determine the causes for failure in the majority of sites, so the trials were repeated to a revised plan during 1953. The latest trials have been carried out as experiments and not as user trials as in 1952. The main soil treatments were applied by Research Branch staff at all nurseries, and many of the variations in the details of treatment inherent in the user type of trial were eliminated in order to obtain a strict experimental assessment of the responsiveness of each soil type.

The trials were done at 13 nurseries in England and Wales, and tested formalin at a standard rate of 0.05 gallons 38 per cent formalin in ½ to 2 gallons of water per square yard of seedbed. All applications were made in January or February, the latest application at any nursery being February 25th. As a result of this it was possible to complete all seed sowing before the end of March.

Sitka spruce and Norway spruce were sown as test species at all thirteen nurseries. Examination of the seedling crops at the end of 1953 showed that while there was still considerable variation in the effects of formalin between nurseries, the treatment was more generally successful than was the case in 1952. With few exceptions formalin had no significant effect on the germination and survival of seedlings, but there were pronounced effects on seedling growth of both test species at many nurseries. Norway spruce showed improved growth at ten nurseries, and Sitka spruce at seven nurseries, out of the thirteen nurseries examined. In only six nurseries did both species respond to treatments. The growth increases were substantial in all those nurseries where a response was obtained.

As in 1952, examination of the soils and records of operations has failed to reveal any feature common to the unresponsive nurseries. The soils on which formalin failed on one or other of the test species ranged from sands with a pH of 4.8 to heavy loam with a pH of 7.0.

Formalin has a number of practical disadvantages for large scale use, the most important being the large volume of water required with existing techniques to secure adequate penetration of the chemical into the soil. In recent experiments chloropicrin has shown great promise as a soil sterilising agent injected at application rates as low as 20 gallons per acre. In view of the greater ease with which such small volumes could be applied in large scale work, it now seems essential to examine the effects of this treatment in more detail. Accordingly, in the current season a series of experiments were started to compare formalin and chloropicrin as partial sterilising agents in a range of nurseries.

In Scotland, at Newton, Morayshire; Benmore, Argyll; and Fleet, Kirkcudbrightshire; experiments were carried out on Sitka spruce seedbeds which were designed to compare chloropicrin injected into the soil at depths of three inches or five inches and 3 to 4 weeks before seed sowing and at rates of 20, 30 or 40 gallons per acre, with the standard formalin sterilisation treatment (i.e. 242 gallons of 38 per cent formaldehyde per acre diluted with 4,800 to 9,600 gallons of water depending on soil moisture conditions). Results from all three nurseries showed chloropicrin to be a more efficient soil sterilising agent than formalin, in so far as it produced seedlings with greater mean heights. In addition chloropicrin significantly reduced hand weeding times at Benmore, although not at Fleet. There was a tendency for chloropicrin slightly to reduce the total yield of seedlings, but this was only significant at the 5 per cent level at Benmore. There were no significant differences between injection at depths of three inches or five inches for either mean heights, total numbers, or weeding times, at any of the nurseries. Only at Newton were there significant differences between the three concentrations of chloropicrin. Here the 40-gallon-per-acre treatment produced seedlings highly significantly taller than the 20-gallon-per-acre treatment. Results are given in Table 1.

HEIGHT GROWTH, YIELD AND WEEDING TIMES OF PLOTS OF ONE YEAR OLD SITKA SPRUCE SEEDLINGS TREATED WITH CHLOROPICRIN AT THREE CONCENTRATIONS AND INJECTED AT TWO DEPTHS, COMPARED WITH FORMALIN TREATMENT AND CONTROL

Table 1

Treatment	Mean Ht. (ins.)			Total Nos. per sq. ft.			Weeding Times mins./sq. yd.	
	Newton	Benmore	Fleet	Newton	Benmore	Fleet	Benmore	Fleet
Chloropicrin (Mean of 3 levels detailed below)	2.01	1.58	3.37	130	129	119	2.8	8.8
Formalin	1.95	1.32	2.13	135	141	129	2.6	7.2
Control	1.29	0.82	1.80	123	153	137	4.2	8.8
Standard Error ±	0.09	0.18	0.16	8	4	5	0.2	0.87
Differences for significance 5%	0.26	0.25	0.46	not	12	not	0.7	not
1%	0.35	0.33	0.62	sigt.	17	sigt.	1.0	sigt.
Chloropicrin								
20 galls. per acre ...	1.79	1.50	3.18	131	131	121	3.1	10.8
30 galls. ,, ,, ...	1.99	1.54	3.33	132	130	119	2.6	9.6
40 galls. ,, ,, ...	2.24	1.69	3.60	128	125	118	2.8	6.0
Standard Error ±	0.08	0.08	0.14	7	4	5	0.2	0.78
Differences for significance 5%	0.23	not	not	not	not	not	not	not
1%	0.31	sigt.	sigt.	sigt.	sigt.	sigt.	sigt.	sigt.
*Depth of Application**								
3 inches	1.96	1.52	3.30	137	131	119	2.6	8.8
5 inches	2.05	1.62	3.36	123	128	120	2.8	8.8

* Differences not significant at any nursery for mean heights, total numbers or weeding times.

The experiments will be resown in 1954 to determine any residual sterilisation effects.

Manuring

Time of Application of Potash and Phosphate Fertilizers

An experiment to determine the effects of applying inorganic phosphate and potash fertilizers at different times before seed sowing was repeated for a second time at Inchnacardoch, Inverness-shire; Newton; Tulliallan, Fifeshire; Benmore; Fleet; and Wykeham, Yorkshire. In this experiment sulphate of potash and superphosphate fertilizers were applied and raked into seed beds at the normal rates, equivalent to 0.40 oz. K_2O per sq. yd. and 0.40 oz. P_2O_5 per sq. yd. respectively, at nine weeks and three weeks before sowing, and on the date of sowing.

Numbers of plants were not significantly affected by any of the treatments at any of the nurseries, and only at Newton and Benmore were there significant mean height differences between fertilizer application treatments. At Benmore, potash applications on the date of sowing, in comparison with the three and nine week before sowing treatments, resulted in lower mean heights of seedlings at the 1 per cent level of significance. At Newton, applications of phosphate both on the date of sowing and nine weeks before sowing resulted in highly significantly lower mean heights, when compared with applications three weeks before sowing. Applying potash either three or nine weeks before sowing gave significantly lower mean seedling heights, in comparison with applications on the date of sowing.

These results are similar to the results obtained in the 1952 series of experiments on this project. The general conclusion to be drawn is that phosphate and potash fertilizers can safely and effectively be applied to Sitka spruce beds at any time from nine weeks before the date of sowing onwards, with indications that about three weeks before sowing may sometimes be slightly better than earlier or later. No damage however has so far resulted from applications at the time of sowing.

Time and Method of Applying "Nitrochalk" to Seedbeds

The experiment started at seven centres in 1952 was again repeated at Inchnacardoch; Littleburn, Ross-shire; Newton; Tulliallan; Benmore and Wykeham. The experiment is designed to compare the effects of equal amounts of "Nitrochalk" applied at different times and in different ways to one year Sitka spruce seedbeds. "Nitrochalk" (15.5 per cent N.) was applied at a rate of 4½ cwts. per acre either as (a) one third dressing before sowing with two subsequent top dressings of one-third each at a variety of dates during June, July or August or (b) no initial dressing but as two equal top dressings during June, July, and August.

Benmore and Tulliallan were the only nurseries where seedlings were significantly taller when "Nitrochalk" was applied entirely as top dressings. At other centres there were no significant differences for mean heights between the two methods of applying "Nitrochalk". At Wykeham and Littleburn, treatments in which a third of the Nitrochalk was applied basally produced a significant increase in yield of seedlings.

Two top dressings in July or August, or one top dressing in July followed by a second in August, produced seedlings which were significantly taller than seedlings which received all or part of the "Nitrochalk" in June. At Tulliallan and Littleburn applications of "Nitrochalk" in July and August produced a significant reduction in the out-turn of plants.

These results do not strictly follow the pattern of results obtained in 1952, variations are slight however, and it appears overall that two top dressings of "Nitrochalk" in July or August, or one top dressing in July followed by a second in August, are the most satisfactory times. No early frost damage has occurred to plants in any of the treatments in either year.

Long-Term Fertility Demonstrations

The large plot trial on acid Bagshot sand at Bramshill heathland nursery, Surrey, was continued in 1953. The trial was established in 1950 to examine and compare the long-term effects of annual applications of organic and inorganic manuring on soil productivity. Each year since the trial was started, all plots have been sown and cropped with Sitka spruce seedlings. Manures were applied each year as bracken/hops or straw/hops compost at 20 tons per acre, or mineral fertilizers at 7.5 cwts. potassic superphosphate and 6 cwts. "Nitrochalk" an acre. Examination of the fourth crop of one year seedlings at the end of 1953 showed no change in the general level of soil productivity under the different manurial treatments (see Table 2).

PRODUCTION AND GROWTH OF ONE-YEAR SITKA SPRUCE SEEDLINGS IN 1953, ON THE LONG-TERM FERTILITY DEMONSTRATION AT BRAMSHILL

Table 2

Manurial Treatment Applied Annually 1950-1953	Total Seedling Production per Sq. Yd.	Seedling Mean Height (Inches)
Control—no manures	839	0.63
Compost	572	1.74
Fertilizers	743	1.66
Compost and Fertilizers	677	1.77
Sig. Diff. (P=0.05)	180	0.17

Compost alone, or in combination with mineral fertilizers, gave a lower total seedling production compared with unmanured or fertilizer treated plots. Compost alone, fertilizers alone, and the combined compost and fertilizer treatments, all increased seedling growth to a similar extent compared with plots receiving no manure for four years. No differences in colour, form or general health of the plants could be observed between plants raised on organic and those raised on inorganic manures. These results are exactly similar to those with the seedling crops of 1950 and 1952. In 1951, growth was considerably greater on fertilizer plots than any other treatment.

A similar long-term fertility demonstration at Teindland woodland nursery, Morayshire, in which both *Pinus contorta* and Sitka spruce are used as test species, continued into its fourth year. Poor quality seed and attacks by birds invalidated any results based on assessments in the *Pinus contorta* section. In the Sitka spruce section a reversal of the previous position relating to mean heights was experienced. In the past artificial fertilizers alone have consistently produced the tallest seedlings, but this year the compost-plus-artificial-fertilizers produced the tallest plants, followed by compost alone, artificial fertilizers only and the control (no manures) treatment. (See Table 3.)

TEINDLAND WOODLAND NURSERY FERTILITY DEMONSTRATION
END OF FOURTH YEAR HEIGHT AND NUMBER PRODUCTION FIGURES FOR SITKA SPRUCE ONE-YEAR SEEDLINGS

Table 3

Treatment		Mean Heights (Ins.)	Total Nos. Per Sq. Ft.	Percentage of Usable Plants (over 1½″ tall)
No manure or compost		0.90	106	7
Artificial fertilizers only		2.16	116	74
Compost only		2.38	126	87
Artificial fertilizers and compost		2.54	120	90
S.E. ±		0.05	6.8	—
Difference for	5%	0.10	Not significant	—
significance	1%	0.28	—	—

The new long-term fertility demonstration at Newton, which includes green-cropping, compost, sterilization, and artificial fertilizer treatments, was sown for the first time. Results showed that the effect of artificial fertilizers on the mean heights of spruce seedlings was far greater than that obtained by the green-crop, compost or sterilisation treatments. Partial soil sterilization by formalin produced only a minor response in height growth.

At Fleet a repeat of the Newton demonstration was started, and green-crop and transplant areas were laid out.

The fertility maintenance demonstration of the original heathland nursery at Wareham, Dorset, continued to be highly productive after regular cropping with seedlings and transplants since it was started by the late Dr. Rayner in 1943, using organic manures and composts for fertility maintenance. Two sections of Wareham nursery have now been set aside exclusively for continuation of this demonstration.

Seedbed Compaction

The 1952 Wykeham seedbed compaction experiment was repeated at Inchnacardoch, Fleet and Wykeham using rollers of approximately 12 inch diameter weighted with 1, 3 to 4 and 6 to 7 cwt. loads. At all three nurseries it was evident that any increase in seedbed compaction resulted in an increase of the speed of germination of Sitka spruce seed during the first few weeks of germination. By July, however, there were no significant differences in numbers of seedlings produced, as between compacted and uncompacted plots at Inchnacardoch and Wykeham; but at Fleet uncompacted beds, and beds compacted with a roller weighing 7 cwts. produced significantly fewer plants than beds rolled with a 1 cwt. or 3 to 4 cwt. roller.

Only at Fleet were the differences in the number and height of the seedlings produced by the compaction treatment significant. At this nursery all treatments increased the mean heights highly significantly compared with the uncompacted control, but the extremes (i.e. the control and compaction with the heaviest roller) reduced the number of plants significantly.

In addition to the compaction of the seedbed before sowing, firming of the seed with a board before applying grit, and also a further rolling of the grit after sowing were tested. These treatments are sometimes employed in normal practice. The firming treatment had no effect, and the final rolling no effect except at Wykeham where it reduced the yield of plants. This was attributed to the coarse Doncaster quartzite chip cover used at this nursery.

It appears from all these experiments that rolling seedbeds before sowing with a medium weight roller (1 to 4 cwt.) is a safe and satisfactory procedure, and that additional firming or rolling is unnecessary. This tentative conclusion will however be tested over several years and also at other nurseries.

Soil Mulching Trials

Experiments started in 1950 at Wareham, Dorset, testing several organic materials applied as soil covering mulches throughout the season prior to cropping with seedlings, were continued. The experiments were started with the aim of obtaining precise information on the growth response of seedlings to such treatment, and some evidence on the mechanism of the effect.

Sitka spruce sown in 1951 on land mulched through 1950 with green bracken or inert cellulose fibre, showed considerably improved growth on those plots which have been mulched with bracken. The inert cellulose material had no effect. No manures were applied before sowing, and the results suggest that a large part of the response of Sitka seedlings after mulching with bracken was due to leaching of nutrients from the bracken into the soil. In 1952 all the plots were split for a further mulching treatment which compared green bracken and weathered sawdust as mulching materials. Prior to sowing in the spring of 1953, all mulches were removed, and one half of each plot was treated with balanced NPK fertilizer. Sitka spruce was sown as the test species in 1953, and measurement of the crop during the year revealed no residual effects of previous mulching treatments. The application of balanced fertilizer before sowing greatly increased height growth on all treatments. These experiments have failed to bring out any consistent benefits of mulching on the growth of subsequent crops. The provision of plant nutrients in balanced fertilizer or compost manuring has given good quality plants irrespective of the mulches preceding the crop.

Seedbed Covering Media

An experiment designed to test the effect of hessian, grit and a quarter-inch thick sawdust mulch cover above Sitka spruce seed was repeated at Inchnacardoch; Benmore; Bush, Midlothian; Fleet; and Wykeham. All treatments containing sawdust greatly retarded speed of germination when compared with grit alone, and grit and hessian, treatments. At the end of the year and at all nurseries, excluding Bush, grit alone treatments produced the tallest seedlings. In most cases grit alone produced fewer plants than sawdust and hessian, or grit with sawdust and hessian treatments. Between nurseries the results were very erratic, and a definite general conclusion could not be reached.

A small trial at Mabie, Dumfries-shire to compare Criffel filter sand, a very rough and angular washed granitic grit of $\frac{3}{8}''$ to $\frac{1}{8}''$ particles mixed with a small proportion of coarse sand, and Fleet sand, an unwashed coarse sand containing a low proportion of rounded small pebbles ($\frac{1}{4}''$ to $\frac{3}{4}''$), were compared as suitable seedbed covering media for Sitka spruce. Criffel filter sand significantly increased the heights and numbers of seedlings, by approximately 25 and 50 per cent respectively.

Soil Conditioners

An investigation into the effects of applications of hydrolysed polyacrylonitrile (Krilium), as a soil conditioner was carried out at Ddwylig nursery, St.

Asaph, North Wales in 1952-53. The soil in this nursery is a sandy clay loam containing 20 per cent clay, and the aim of the investigation has been to test the effect of Krilium on soil aggregate formation and working properties, and its effect on the growth and production of seedlings of common conifer species.

Experiments were repeated on the same land over two seasons in 1952 and 1953. Krilium was applied to roughly prepared seedbeds in April of each year at 2 oz. per square yard. Applications were immediately cultivated into the soil to a depth of three inches. In both years the Krilium was applied after the beds had received standard basal dressings of potassic superphosphate. The effects of the treatment on the soil were assessed by visual examination and analysis of soil samples to determine the content of water-stable aggregates. The results of these analyses in both years showed only slight increases in soil aggregate formation on Krilium-treated plots.

In both years, seed of five common conifer species was sown one week after Krilium application, to provide a measure of the effects of treatment on seedling growth. Summing up results over all species the numbers of seedlings at end of season 1952 were appreciably lower on Krilium plots. Re-treatment of Krilium plots in 1953, followed by re-sowing, resulted in crops showing considerable depression of seedling numbers on treated plots, particularly in the case of Sitka spruce, Norway spruce, Douglas fir and Japanese larch. In addition the height growth of Scots pine, Japanese larch, Douglas fir and Norway spruce was appreciably lower on Krilium plots. The total effect of the treatments on the utility of the 1953 seedling crop can be seen from Table 4, which shows the production of usable, i.e. transplantable seedlings per lb. of seed.

PRODUCTION OF USABLE SEEDLINGS IN THOUSANDS PER LB. OF SEED ON KRILIUM-TREATED PLOTS IN 1953

Table 4

Species / Treatment	Scots pine	Japanese larch	Douglas fir	Norway spruce	Sitka spruce
Control	15.1	21.5	8.1	4.4	9.2
Krilium	10.8	13.5	5.0	1.7	2.4

In view of these reductions in plant yield, the treatment must be considered a failure when judged in terms of its short-term effects on plant production. Observations in the field indicate that Krilium had no detectable effect on the working properties of the soil in 1952, but in 1953 it was reported that treated soil was undoubtedly more friable and produced better tilth conditions than untreated soil. Unfortunately this was not accompanied by any increase in yield of current crops. The mechanism of the injurious effect of Krilium on seedling germination and survival is not understood, but it seems possible that the trouble may originate from unreacted Krilium remaining in the soil. This is now under investigation, and all plots have been resown in 1954 with no further Krilium treatment.

In Scotland the 1952 Tulliallan experiment in which Krilium soil conditioner was applied at rates of 0.03, 0.06, 0.09 and 0.12 per cent by weight of soil, was resown with Scots pine and Sitka spruce. Although Krilium had no pronounced residual effects upon speed of germination, mean heights or total yields of plants, it was reported that Krilium-treated clay soil was far more friable than untreated soil.

Chemical Control of Weeds in Forest Nurseries

Weed Control in Fallow Land

Experiments were started in the spring of 1953 at Eversley nursery, Bramshill Forest, Hampshire, to test a number of chemicals as complete weedkillers for application to fallow land. It is common practice in many nurseries in England and Wales to allow land to lie fallow once every three or four years, and this provides an opportunity to apply weed control treatments of a type which could not be considered during crop years. The chemicals under test were applied to the land as sprays in spring or autumn 1953, in each case one month after preparatory cultivation. Examination of weed development throughout the season following spring treatment showed most promising results. Sodium chlorate, applied at 300 lb. in 200 gallons of water per acre, gave a high degree of control of annual weed species. Sodium trichloracetate (TCA) gave somewhat variable results and application of 120 lb. per acre gave a high degree of weed control, but rates up to 240 lb. per acre were necessary for complete eradication of weeds. Chlorphenyl dimethylurea (CMU) applied as a wettable powder in water at 2.5 to 40 lb. in 200 gallons per acre was highly toxic and persistent even at the lowest dosage. Application of 20 lb. per acre gave almost complete control of annuals throughout the season of treatment.

Perennial weed species were more resistant than annuals to all treatments. *Agropyron repens* or couch grass, which was the only perennial commonly present, was killed only by the heaviest rates of TCA. CMU at 40 lb., and sodium chlorate at 300 to 600 lb. per acre checked this species very severely, but regrowth appeared several months after treatment. Autumn application of chemicals seems to have given similar results to spring treatment, although it is too early to draw final conclusions.

Sample portions of the plots treated in spring or autumn 1953 are being cropped in 1954 with seedbeds and transplants of a range of common conifer and hardwood species. The object of this is to examine the effect of the treatments on weeding costs, and to assess any residual effects the chemicals may have on the growth and development of the crop species. Observations up to May 1954 indicate that the highly soluble chemicals TCA and sodium chlorate appear to have no harmful residues. CMU, however, is more persistent; and severe foliage discoloration has appeared on transplants of Japanese larch on plots which received more than 10 lb. CMU per acre. Pine, spruce, Douglas fir and beech show no injury, but effects cannot be judged finally until the end of 1954.

These trials are being continued, and in addition tests are now under way with other complete weedkillers, notably pentachlorophenol—2, 4-D mixtures. Phenyl dimethylurea (PDU), a compound which is less persistent than CMU, but may have valuable temporary weed control properties, is also under test.

Weed Control in Seedbeds

As in 1951 and 1952, a series of large-scale trials were carried out in ten nurseries in England and Wales with the object of testing pre-emergence and post-emergence applications of mineral oils under a variety of conditions for weed-control in seedbeds. Results have been consistently good, and high degrees of weed control obtained with negligible crop damage providing certain maximum application rates were not exceeded. Application of vaporising oil as a pre-emergence spray has resulted in a general reduction of 50 to 75 per cent in the costs of handweeding during the season of treatment. Post-emergence spraying with white spirit for controlling weeds germinating after the pre-emergence treatment, has resulted in a further reduction of about 20 per cent on the handweeding costs for the season. The percentage reduction in weeding costs is remarkably constant over a wide range of conditions, and the above values can be taken as a reasonably reliable index of the general effectiveness of the treatments. Some tree seedling injury was caused by post-emergence spraying, but generally white spirit at rates of 10 to 30 gallons per acre gave a high degree of weed control if applied at the proper times, and repeated spraying at these rates has not had serious injurious effects on the tree crop.

Experiments during the year testing a range of rates of vaporising oil as a pre-emergence spray showed that under some conditions, several species, including Scots pine and Japanese larch, are capable of withstanding applications of 200 gallons per acre without injury. However this is certainly not general, and in practice it has been found that the application rate should not exceed 60 gallons per acre. Pre-emergence sprays have normally been delayed until a few days prior to tree emergence, to allow the maximum numbers of weeds to germinate before treatment. Experimental results in 1953 support this practice, and showed that spraying immediately after sowing, or at two or three weeks before tree emergence, were less effective weed-control treatments. It is interesting to note that the earlier pre-emergence sprays were not completely ineffective, even though in some cases no weed growth had appeared at the time of spraying. It was also shown that vaporising oil can be used with effect to kill weeds which may appear on seedbeds before sowing. If this can be done two or three days before seed sowing, no injury to the tree seed seems likely.

A series of experiments testing the effects of dosage and date of post-emergence application of white spirit were completed at Kennington nursery, Oxford. The results confirmed the present general conclusion that, with the exception of larch and Douglas fir, the majority of conifers can withstand repeated spraying at rates up to 30 gallons per acre. Seedlings are relatively sensitive during the first six weeks after emergence, and rates should not normally exceed 10 gallons per acre at this stage. Application of emulsions of white spirit in water, or of water in white spirit, appear to have no advantage over the use of white spirit alone. Emulsions of both types have shown themselves to be less toxic and no more selective between crop and weed species than straight oil applications.

Allyl alcohol applied as a soil "drench" to the seedbed before seed sowing resulted in very great reductions in weedgrowth throughout the season. Application at a range of concentrations from 0.2 to 0.8 per cent at one gallon of aqueous solution per square yard had no injurious effects on the subsequent crop of Sitka spruce seedlings, and rates of 0.4 per cent and over, reduced weeding by 95 per cent compared with controls. However this chemical is dangerous and offensive to handle, and even though it is a highly effective weedkiller it is doubtful whether it could ever be used in large-scale practice as a soil drench treatment. Mechanical injection of the soil with small volumes of the concentrated chemical seems a possibility, but this has not yet been tested experimentally. Undecylenic acid, which in previous experiments has shown some promise as a selective weedkiller in spruce seedbeds, gave disappointing results in 1953 at both Ampthill and Kennington nurseries. Repeated spraying, throughout the season, of concentrations from 0.25 to 1.5 per cent in water at 100 gallons per acre showed that the 1.0 per cent solution, which was the minimum concentration for appreciable weed control, also caused considerable injury to both spruce and pine seedlings.

Trials with SES, a 2, 4-D formulation becoming actively phytotoxic only after contact with soil for several days, were continued after promising results in 1952. SES has given appreciable savings in weeding times when applied as a post-emergence spray at rates up to 2 lb. of the salt in 100 gallons water per acre. As many as four applications during the season caused no apparent injury to rising one-year seedlings of Scots pine and Sitka spruce.

Weed-control in Transplant Lines

Experiments testing mineral oils for weed-control in rising one-plus-one transplant beds of a range of species were continued at Bramshill nursery, Hampshire, and Savernake nursery, Wiltshire. The 1953 trials were carried out on similar lines to those of 1952 described in *Rep. For. Res. Year Ending March,* 1953. Both vaporising oils and white spirits were tested as single and repeated applications from May to October, at dosages from 60 to 120 gallons per acre. Repeated overall spraying at the highest rate of 120 gallons per acre caused some checking of transplant growth, particularly in the case of Douglas fir. In general the species under test, which were Corsican pine, Norway spruce, Sitka spruce and Douglas fir, were considerably more resistant to oil sprays than was the case in 1952. Plants did not vary greatly in sensitivity over the season.

Overall spraying in mid-summer caused considerable crop damage in 1952 trials, and interest was drawn to the possibility of spray placement between the lines of plants to avoid such injury. Inter-row spraying of transplants has given good results with negligible crop damage, and it seems that this technique may prove a safe and effective method of weed-control in practice. An adjustable tractor-mounted spray boom for accurate inter-row spraying has been developed during the year, and large-scale trials are now proceeding. With this equipment the weedkiller can be concentrated at soil level, and the amount reaching the growing shoots of the transplants is minimised. Up to date, trials of vaporising oil and white spirit applied in this way have given a high degree of weed-control from repeated spraying at rates of 30 to 40 gallons per acre.

Chemical Control of Weeds in Scottish Forest Nurseries

Extensive trials of pre-emergent sprays with Tractor Vaporising Oil at 60 gallons per acre, and repeated post-emergent sprays of Shell weedkiller "W", a form of white spirit at 10, 20 or 30 gallons per acre, were conducted by local Conservancy staffs in co-operation with Research Branch at several of the larger Scottish nurseries. A range of common conifer seedbeds, including Scots pine, mountain pine, European and Japanese larch, Norway and Sitka spruce, and Douglas fir, were used. End-of-season results showed that pre-emergent sprays of T.V.O. had been highly successful and had reduced overall weed growth by 50 to 65 per cent. Post-emergent sprays were successful in reducing subsequent weed growth and produced only slight adverse effects upon seedling numbers and mean heights. A remarkable finding from the experiment was the very slight damage caused to the usually sensitive larches by post-emergent sprays of 20-30 gallons per acre.

Seedbed Irrigation

Trials of an overhead sprayline sprinkler system for seedbed irrigation were continued into their fourth year at Kennington nursery, Oxford. The experiment was increased in size at the beginning of 1953 to include tests of a range of seed sowing dates within each irrigation treatment. Under each irrigation treatment, the aim has been to maintain soil moisture at field capacity throughout the season by applying water at rates and frequencies determined by the rate of soil moisture loss. Two watering regimes have been compared. In the first regime, plots have been irrigated whenever the soil moisture deficit reached 0.5 inches, and in the second when the deficit attained 1.5 inches. In 1953, the first treatment involved irrigation at relatively frequent intervals from April to September, and a total of 8.49 inches of water was applied under this regime, compared with 3.6 inches under the second treatment.

As in previous years, Sitka spruce was the main test species, but in addition subsidiary plots were sown with Corsican pine, Douglas fir, Japanese larch and *Tsuga heterophylla*. Examination of the seedling crops at the end of 1953 showed large crop responses to watering, even though the rainfall during the growing season had been above average. Irrigation increased the total numbers of seedlings produced very considerably for Sitka spruce and *Tsuga heterophylla*, but there was no effect on seedling production in the case of Douglas fir, Corsican pine and Japanese larch. Both watering regimes greatly increased the growth of Sitka spruce, Douglas fir and Japanese larch. Corsican pine showed no response at all to watering, while *Tsuga heterophylla*, which showed a great increase in numbers of seedlings on irrigated plots, produced no corresponding increase of seedling growth. These results are in broad agreement with those of previous seasons. Sitka spruce has proved to be the most responsive of the common conifers to watering treatment, and in each year of the trial, irrigation has increased the yield and growth of seedlings of this species. The scale of the increases has varied according to the season's rainfall, but in all it has been possible to ensure a high level of germination, survival, and growth, over a period of years in which very variable production has been obtained on unwatered plots.

Comparison of compost, mineral fertilizers, and compost plus fertilizers as manurial treatments within each irrigation plot showed that all manures increased seedling growth, but the increases were considerably greater on watered than unwatered plots (see Table 5). Also irrigation had a negligible effect on seedling growth on unmanured plots, in contrast with the pronounced response to water on manured plots.

EFFECT OF IRRIGATION AND MANURING ON SITKA SPRUCE SEEDLING MEAN HEIGHT IN 1953

Table 5 Mean Height (Inches) October, 1953

Manurial Treatment	Irrigation Treatment		
	Control	Treatment 1*	Treatment 2*
Control	1.81	1.54	1.96
Compost	2.29	3.02	2.80
Balanced mineral fertilizers	2.34	3.06	2.79
Compost + fertilizers	2.39	3.31	3.01
Sig. Diff. (P.=0.05)	0.30	0.37	0.36

(*Note:* *Treatment 1=Irrigation to field capacity when deficit reaches 0.5 ins.
Treatment 2=Irrigation to field capacity when deficit reaches 1.5 ins.).

Sowing date was an important factor in determining seedling production and growth, irrespective of irrigation treatment. Plots sown in March produced a larger number of seedlings than plots sown in April or May, similarly sowing in March or early April produced larger seedlings than later sowings. These effects were so large that early sowing without subsequent irrigation produced seedlings equal in size to those raised on late sown plots with the best irrigation treatment (see Table 6). However irrigation resulted in growth increases on beds sown at all dates.

EFFECT OF IRRIGATION AND DATE OF SOWING ON SITKA SPRUCE SEEDLING MEAN HEIGHT IN 1953

Table 6 Mean Height (Inches) October, 1953

Sowing Date	Irrigation Treatment		
	Control	Treatment 1	Treatment 2
March 28, 1953	2.32	3.08	2.72
April 14, „	1.88	2.44	2.24
April 30, „	1.49	2.12	1.88
May 16, „	1.34	1.96	1.63
Sig. Diff. (P=0.05)	0.54	0.59	0.38

These results indicate that the date of sowing is a key factor in determining production and growth even if irrigation is available.

Root Pruning of Seedlings

Experiments were continued at Bramshill nursery, Surrey, in 1953 to examine mechanical undercutting of seedlings *in situ* as a possible cheaper alternative to the normal transplanting technique. The effects of the season of pruning, and the depths at which the plants are cut, are under investigation for Corsican pine and Douglas fir. The first trials were started in 1951, and results to the end of 1952 are described in *Rep. For. Res.* 1953. Experiments started in 1953 are still under way, and final results are not yet available.

In Scotland experimental work on undercutting seedbeds was continued at Newton, Tulliallan, Fleet and Mabie Nurseries and plants from the 1951 experiments were planted out in the forest for growth and survival studies. Undercutting was done at a depth of four inches. Experimental data to date indicates that:

(*a*) Scots pine is more responsive than Japanese larch in producing root fibre following undercutting.
(*b*) Transplanting produces more root fibre than undercutting.
(*c*) Undercutting in March only slightly increases the amount of root fibre.
(*d*) Undercutting and transplanting both check the amount of shoot growth but transplanting has a more pronounced effect in this respect than undercutting.

More detailed investigations are now proceeding, and experimental work is being conducted on time and depth of undercutting and density of sowing. The usefulness of undercutting seedlings as a cheaper alternative to transplanting can only be evaluated by the results of forest planting experiments over a number of seasons, and on a variety of sites. Such experiments have been commenced, but it will be some time before reliable indications are obtained.

Intensive Methods of Raising Sitka Spruce Seedlings

At Tulliallan Nursery this work continued on a small scale. The object of the 1953 work was to use overhead electric light bulbs as a continuous source of heat and light, to promote rapid germination and growth in the early part of the year. For this purpose 15, 25 and 40 watt electric light bulbs were spaced at regular intervals inside and outside a "Dutch light" frame, to give loadings of approximately 13, 22 and 35 watts-per-square-foot respectively. Seed was sown in boxes five inches below the level of the light bulbs in early February, inside the frame, and in early March outside the frame.

The effect of the heat produced by the 35 watt-per-square-foot loading inside the frame was to advance the date of germination by 36 days, to 10 days net. The 22 and 13 watt-per-square-foot treatments germinated at successive three day intervals after the 35 watt treatment. In all cases germination was completed in 6 to 7 weeks.

Outside the frame, seed under the 35 watts-per-square-foot loading germinated first, and 27 days before the control. The 22 and 15 watt-per-square-foot treatments germinated simultaneously 12 days after the 35 watt treatment.

Overhead lights were switched off in mid-May and the plants inside the frame were "hardened off" in 10 days before the complete removal of overhead glass.

These experiments indicate that quick germination and early growth, even before the commencement of the normal growing season, can be obtained by the use of overhead light, which also provides warmth in the surface layers of the soil. The results are similar to those obtained in previous years with the aid of both bottom heat (at 7.5 watts per sq. ft.) and overhead illumination at 4 or 5 foot-candles, but that combination requires more electric current.

Storage of First Year Seedlings from Heathland Nurseries

An experiment to test the efficiency of several cheap methods of storing Scots pine, *Pinus contorta* and Japanese larch one-year-old seedlings from Teindland heathland nursery was conducted in co-operation with East Conservancy (Scotland). The treatments under test were the storage of plants, lifted from the nursery at monthly intervals from November 1952 to March 1953, in:

(*a*) Uncovered boxes in the forest.
(*b*) Boxes covered with roofing felt in the forest.
(*c*) Boxes in a well ventilated shed.
(*d*) Moss sheughs (shallow trenches) in the forests.
(*e*) Soil sheughs in the open nursery.

In all cases plants were stored both loosely and in bundles.

All the plants, whatever their period of storage, were lined out in the nursery in early April 1953, and were assessed in October 1953 for survival rates to give a measure of success of the storage treatments. The results obtained showed that storing plants in forest or nursery sheughs, irrespective of date when storage began or whether in bundles or loose, were the most satisfactory treatments, giving a survival of 75 to 94 per cent (mean of all storage periods) depending on species. When plants were stored in a well ventilated shed, no more than 7 per cent survived, and in some instances every plant died. Storage out of doors in boxes with a felt cover gave 27 to 29 per cent survival, and in boxes without a felt cover 61 to 75 per cent survival.

Growth Inhibitors

Scots pine and Douglas fir seedlings which had shown a significant reduction in height growth, and had suffered a contortion of their needles following applications of maleic hydrazide in 1951, grew normally when lined out at

Tulliallan nursery in 1953. Maleic hydrazide is a growth inhibitor which may possibly be of use in delaying the flushing of plants which cannot be planted at the correct time in spring, or which require retention for an additional year in the nursery. Observations on the treated plants are to be extended into the forest to determine whether there are any long-term residual effects of the maleic hydrazide.

Season and Date of Lining-out

The 1950 lining-out experiment was again repeated at Inchnacardoch, Tulliallan, Benmore, Mabie and Wykeham nurseries, using two-year-old Scots pine and Sitka spruce seedlings. Lining-out took place at intervals from late May and early June at Benmore and Inchnacardoch, and early July at the remaining nurseries, to early April 1952. Plants were separated into height classes at the time of lining-out in order to determine the relationship between initial size and subsequent survival and growth.

Scots Pine Seedlings Between One and Two Years Old. At all nurseries, except Wykeham, lining-out in July and August gave good results and at Benmore and Inchnacardoch, June also provided excellent yields of usable transplants. September and October results were not satisfactory at Tulliallan, Mabie or Wykeham. November and spring treatments were generally satisfactory at all nurseries. In all cases plants which were between three and five inches tall succeeded better than plants less than three inches in height.

Sitka Spruce Seedlings Between One and Two Years Old. In the two high rainfall nurseries of Benmore and Inchnacardoch, all dates of lining out were successful, but at Tulliallan and Mabie, July, March and April were the only successful times. No treatment gave satisfactory results at Wykeham where the casualties were extremely high this year. Again plants which were over three inches tall succeeded better than plants under three inches in height.

SILVICULTURAL INVESTIGATIONS

By R. F. WOOD, *Silviculturist* (South), and

M. V. EDWARDS, *Silviculturist* (North)

In this summary, the work that is being done by Silviculturist (North) in Scotland and Northern England (down to a line from the Humber to the Mersey), and by Silviculturist (South) in the rest of England and also in Wales, is brought together, as the same or similar subjects are frequently being investigated in both northern and southern areas.

Trials of Species and Work in Arboreta

Planting was continued at the main centres—Bedgebury (Kent), Thetford (East Anglia), Wareham (Dorest) and Beddgelert (Caernarvonshire). In the north the collections at Teindland (Morayshire), Clashindarroch (Aberdeenshire), and Kielder (Northumberland) were extended.

Pilot Plots on Limiting Sites

The major silvicultural project in the North continues to be the planting of trial blocks on difficult sites, using the techniques developed in earlier intensive experiments. The limits for successful establishment of *Pinus contorta*, using ploughing and phosphatic manuring, have not yet been determined. So in the current year, plantations on land considered unplantable by present standards, have been made in Hoy, Orkney (4 plots totalling 32 acres); near Lael Forest, Ross-shire (5 acres); near Dundonnell, Ross-shire (10 acres); and in Carrick Forest, Ayrshire (2 plots totalling 9 acres). All these areas are in considerable exposure, all but those in Hoy lie at or over an elevation of 1,000 feet, and soil conditions are poor with the exception of two of the Hoy sites. In the majority of these plantations *P. contorta* is the main species. Sitka spruce is used in areas of better soil quality, but generally these are of small extent. In the most exposed plantation on Hoy, however, sited on the best land available, Sitka spruce becomes the main species, as that most likely to survive the exposure. The plantation at Lael marks a new departure in the post-war series in that for the first time the site for the plot was considered unploughable by normal standards. In the event, part has been ploughed using standard tackle, and the remainder will be prepared by hand next year. Costs will be of particular interest here.

In 1949 work was extended from the long-established research centres at Inchnacardoch, Teindland, Allerston and elsewhere to separate afforestation trials in different parts of the country. The total number of the trials is now over thirty, comprising about 350 acres of experimental planting. The area of individual trials ranges from four to eighty acres.

One further experiment related to these pilot plots is the planting on ploughed ground of a five-acre block at 1,250 feet in Inchnacardoch Forest, Inverness-shire. This plantation adjoins older smaller experiments planted by hand methods, and the object is to extend the planting limit upward.

Afforestation of Special Types of Ground

Croft Pascoe, Cornwall

An experimental area has been selected, and pilot experiments established on this Cornish heath. It is of special interest since it is on the Serpentine, a geological formation of which we have little experience. Lying on the Lizard Peninsula it is also considerably exposed. Experiments have included trials of species, ploughing methods, manuring, and nursing by means of broom. Pioneer crops set out for shelter consist mainly of *Pinus radiata* and *Pinus pinaster*.

Wilsey Down

The previous season's small-scale work having shown promising results in the establishment of broom, larger-scale experiments have been laid down. These are designed firstly to investigate methods of bringing Sitka spruce crops out of check, secondly as trials of species on this difficult site. The experiments include the use of broom and *Pinus contorta* (of coastal origin) as nurses. Manurial comparisons have also been made.

Shelter Plantations

A shelter block was planted by the Department of Agriculture for Scotland at Watten, Caithness, to Research Branch specification. The aim was to make a "farmer's plantation" using modern technique adapted to the capacity of the average farm. The soil is fairly good but exposure severe. A light plough was used and "modern" species, i.e. lodgepole pine, Japanese larch and Sitka spruce, with phosphatic manuring, rather than the past favourites such as Scots pine, European larch and Norway spruce. It is hoped that the six acre plantation will produce fencing materials and small timber, besides giving shelter to stock.

Mixtures

An experiment laid down at Moreton Heath, Wareham Forest, compares crops of Scots pine and red oak (*Quercus borealis*), pure and in mixture. It is intended as the first of a series of simple experiments, an important objective of which will be to provide valid comparisons of the effects of species on the site.

Establishment of Hardwoods in Scotland

At Brownmoor Forest, Dumfriesshire, experiments were laid down to compare methods of planting of wych elm and gean using both seedlings and transplants of different ages. In addition an experiment was started to determine the effect of urea formaldehyde "flash" (containing 14 per cent nitrogen) as a manure, and sawdust and grass cuttings as mulches, for the rapid establishment of sycamore plantations on difficult grass sites. Additions were also made to the collection of hardwood plots on both the Whitehill and Main sections of the forest. Species plots of beech, gean, wych elm, and pedunculate and sessile oak were planted at Ross Priory in Garadhban Forest, Dunbartonshire, and also repetitions were laid down of the oak nursing experiments planted last year at Brownmoor, in which gean, wych elm, European larch and Norway spruce are used as nurses round nine- or twelve-plant groups of oak. A provenance experiment comparing beech of south Scottish provenances was planted at Brownmoor and Garadhban forests.

Provenance of Seed

Douglas Fir

A trial of Douglas fir seed sources representing the principal climatic zones of the states of Washington and Oregon, (Mr. F. E. Manning's collection) was planted at two localities in Scotland in 1953, namely a large-scale experiment at Laiken forest (Nairnshire) and a smaller one at Glentress (Peebleshire). In 1954 the same set of provenances were planted out at Mortimer Forest (Herefordshire), St. Clement (Cornwall), Bryn Mawr (Cardigan) and Shouldham (Norfolk). The planting areas have been chosen so as to provide good contrasts in moisture and temperature factors including frost-free period. The 1953 plantings at Laiken showed less than 10 per cent casualties, while those at Glentress showed up to 20 per cent losses at the end of the first year.

Scots Pine: East Scotland Provenance Trial. (See also page 78.)

In 1951 seed was collected from a number of selected seed stands in the East Conservancy of Scotland. Details recorded included elevation, site quality, age and quality class. They were classified by Mr. J. D. Matthews, the Commission's geneticist, on a visual scoring basis according to form and vigour, and according to the exposure zones of M. L. Anderson. There were found to be significant differences in seed size and viability when the seeds were tested by the tetrazolium method, and there were also significant differences in nursery performance.

In 1954, when the plants were one-plus-one-year transplants, they were planted at three sites of varying climatic severity. Glenlivet Forest in Banffshire, the worst site, is high, relatively infertile and very exposed. Glen Isla Forest

(Angus) is moderately exposed but on fair heather ground, while at Laiken Forest (Nairn) optimum conditions for pine growth are found. Here the soil is good, exposure slight and the climate equable. At Glenlivet, planting was on land ploughed at five feet furrow spacings, but elsewhere the plants were directly notched in.

Pinus contorta

Recent supplies of coastal lodgepole pine (*Pinus contorta*) have come mainly from Lulu Island, Vancouver, British Columbia, and several small experiments have been commenced to compare this provenance with others. Two lots of seed from this source, supplied by different seed merchants, were sown in 1950, and varied as much between each other as with an inland provenance, at the end of the nursery stage. In 1951 another lot of Lulu Island seed was compared with inland seed from Shuswap Lake, B.C., and the former was significantly poorer in growth at the end of the nursery stage. Observation on these plants has been continued after their planting in the forest at Watten, Caithness; Achnashellach, Wester Ross; and Inchnacardoch, Inverness-shire.

In 1954 an experiment to test two northern provenance of *P. contorta* was laid down at Watten and at Kielder forest, Northumberland. They are from Haines and Hollis, Alaska, and they will be compared with the Lulu Island provenance, and also with one from home-collected seed.

Sitka Spruce

Plants from seed collected at Hollis, Alaska were planted in 1954 at Strathy Forest, Sutherland, and Kielder Forest, Northumberland, in an experiment comparing them with plants from the usual Foresty Commission source of Sitka spruce, the Queen Charlotte Islands. The latitude of the Alaskan provenances corresponds more closely to that of North Britain, and they may be especially valuable in the islands and coastal parts of Scotland.

Oak.

A trial of the progenies of a number of well-known stands and individual trees was planted at Penyard in the Forest of Dean. Both pedunculate and sessile oaks are represented.

Ploughing

The third and last of a series of cultivation experiments on heathland was planted at Harwood Dale, Allerston Forest, Yorks. The methods of ploughing used at Teindland, and described in the 1952 *Report on Forest Research*, were employed. The ground was difficult, with large boulders, and provided a rigorous test for equipment. The tine type of plough made a good job, without the breakages which occurred with the RLR ploughs which are normally employed in the district.

All these experiments contain Scots pine as a standard crop, but it is of interest to note the "possible economic crops" chosen for trial on the three areas in the light of nearby experiments and experience:

Teindland, Morayshire:	800 ft.	Lodgepole pine with Japanese larch.
Devilla, Fifeshire:	250 ft.	Scots pine with Japanese larch (This site is old woodland).
Harwood Dale, Yorkshire:	800 ft.	Corsican pine with Japanese larch.

This illustrates both the high opinion held at present of the value of the Japanese larch in mixed plantations on heaths (it would not be recommended for pure plantations at 800 feet) and also the relative silvicultural value of the pine species from north to south. The use of Corsican pine is in fact a calculated risk, but early growth at least is greatly superior to Scots pine.

Draining

A large-scale draining experiment was undertaken on *Molinia* peat in the Forest of Ae, Dumfriesshire, to compare deep main drains at wide intervals with the current practice of 18 inch deep drains at about half chain spacing (20 chains per acre). The latter were cut with the single mouldboard Cuthbertson plough, while the deep drains were taken to almost 30 inches with a specially adapted model and will later be deepened to perhaps 3 feet. Two intensities of deep drains were used, at two-chain and one-chain intervals, equivalent to five and ten chains per acre respectively. The ground between was ploughed for turfs with the double mouldboard Cuthbertson plough, and planted with Sitka spruce. The plots are laid out side by side in five randomised blocks, each plot being about six chains long and three chains wide. Costs of upkeep of the various drain systems will be of interest. The effect on rooting and stability will be observed, and it is hoped indications will be obtained as to the way in which the drains in existing crops should be developed over the rotation.

Manuring in the Forest

Trials continue with the object of assessing the value of ground mineral phosphate in terms of increased timber production, on land where phosphate is not *essential to growth* but may affect the *rate of growth* materially. In addition a series of experiments was started to test triple superphosphate. The high phosphate content of this fertilizer could be of great value in reducing transport and distribution costs, which on large planting schemes form a high proportion of the total cost of manuring; for equal dosage only one-third the weight is required as compared with ground mineral phosphate. The use of highly soluble manures, known to be dangerous in contact with tree roots, raises again the question of placement, and this is being investigated.

Spacing in Plantations

Work continued on the application of experimental treatments to the series of spacing experiments on conifers laid down in 1935. The principal lines of approach are to study the effects of initial spacing on stem form, knottiness, and timber quality, on crops which have been allowed to reach a common stand density; in other series an effort will be made to maintain the different rates of girth increment resulting from the initial spacings by differential thinning treatments. Here the main object is to provide timber of contrasting ring widths from a common site. This will be valuable for subsequent investigations into timber quality.

Pruning

A comparative trial of the Wolryche-Whitmore pruning chisel and a standard type of saw was carried out at Alice Holt, the pruned species being Sitka spruce. Though the material was not ideal for the chisel (knots being a little too tough and large), the results obtained with it were on the whole encouraging.

Arboricides

Further work on *Rhododendron ponticum*, confirms that treatment of freshly cut stumps is the most profitable line. Ammonium sulphamate and the "growth substances" 2,4D and 2,4,5T (the latter being applied in oils) are the most promising substances.

Rabbit and Deer Repellents

Work on rabbit repellents has continued, and a note on the results so far obtained will be found elsewhere in this report. (See page 148). A trial of a number of substances (mainly proprietary) designed to protect trees from deer damage, was carried out at Ringwood with red oak, and at Rockingham with poplars.

TREATMENT OF DERELICT WOODLANDS

By A. D. MILLER, *Assistant Silviculturist*

THE bulk of present research on the rehabilitation of derelict woods is devoted to establishing a series of experiments to compare the type of crop produced, and the costs involved, in a number of broadly different methods of treating the principal types, which are classified in terms of both cover and site characteristics. In this work emphasis is put on the effects of differences in the intensity of effort involved in the various treatments.

During the year four new experiments have been established in different parts of the country, involving a total area of about 50 acres. The types treated were:—

1. High cover of mixed hardwood species on a clay soil at Marelands, Alice Holt Forest, Hants.
2. Thicket of cherry laurel (*Prunus lauro-cerasus* L.) on a loamy soil at Glyn Forest in Cornwall.
3. Low cover of mixed hardwoods at Hursley Forest, Hants.
4. Low cover of mixed hardwoods at Penyard Park, Forest of Dean.

All the work on these sites has been recorded and costed.

Maintenance of existing experiments at:

1. Weston Common, Alton Forest, Hants.
2. Verinditch Chase, Gardiner Forest, Wilts.
3. Well Covert, Haldon Forest, Devon.
4. Halton Wood, Coed y Goror Forest, Denbigh.
5. College Wood, Bardney Forest, Lincs.,

has proceeded as and when necessary, all forest operations being costed.

Work has also been started on two experiments rather different in character; one of these at Weston Common, Alton, is to compare different ways of treating and thinning the coppice growth from young sycamore stools and to observe any resulting differences in growth. The second uses a factorial layout to compare the effects on the soil profile and tree growth of three different drainage intensities, and also to compare the growth of a number of species and mixtures on a heavy clay soil at Waterperry Wood, Bernwood Forest, Oxfordshire.

ECOLOGICAL INVESTIGATIONS

By J. M. B. BROWN, *Forest Ecologist*

MUCH of the ecological work has consisted of soil and vegetation studies of experimental sites in Cornwall and Dorset, and the laboratory examination of soil samples derived from experimental sites, or submitted by other sections.

Natural Regeneration of Beech

In the field further attention has been given to ecological factors influencing the survival and growth of beech natural seedlings, with special reference to Watlington Forest in the Chilterns, where seedlings derived from the 1950 mast are being experimentally fostered by various degrees of canopy opening. One striking effect of this thinning, which was made in March, 1952, is the abrupt and locally smothering increase of bramble (*Rubus fruticosus*) and tufted hair grass (*Deschampsia caespitosa*). Such troublesome weed growth, of bramble in particular, is of course a familiar factor in the regeneration of beechwoods. Yet the observations have shown that the risk of a moderate opening of the canopy has to be taken. Without it the seedlings suffer from lack of light and from the competition for water and mineral plant foods with the parent trees: while the wind, particularly on sites such as Watlington, sweeps over the bare floor of the beechwood and adversely affects the growth and health of the seedlings.

In the early months of 1954 some additional treatments, designed to elucidate further the significant factors, were applied. These consist of trenched quadrats and of applications of ground chalk and a general artificial fertiliser in a replicated layout.

Shade and the growth of oak seedlings

In Markham Oak Nursery, Alice Holt Forest, acorns were sown under artificial shade and in the open seedbed in April, 1952, and the results of two years growth under these conditions were assessed in autumn 1953. There were three intensities of shade, transmitting approximately 40 per cent, 15 per cent and 7 per cent of the full light received in the open treatment. Photo-electric readings of the relative light intensity among the shaded seedlings were remarkably consistent throughout the 1953 growing season: in 1952 they were somewhat more variable and generally a little higher in the early summer.

The results were broadly parallel to those previously reported for beech seedlings (*Report on Forest Research* 1951-52) under a similar, though not identical, range of light intensities. Height growth was significantly greater in the 40 per cent light treatment, and significantly less in the 7 per cent light treatment, than in the full light treatment or in the 15 per cent light treatment, in which the seedlings did not differ significantly in mean height. The differences were due almost wholly to the 1953 increment: in 1952 the height increment appeared to be largely governed by the reserves of food in the seed. Dry weight was, however, greatest for the open-grown seedlings. This was due to a very significant difference in mean root weight (dry) between the full light and the 40 per cent light treatments; the latter actually showed a greater shoot weight, but the difference was not significant. Thus the root/shoot ratio was significantly greater in the full light treatment than in the 40 per cent light treatment (3.14 as against 1.8). In the more strongly shaded treatments involving 15 and 7 per cent of full light, both shoot and root were lighter in weight, but the root/shoot ratio did not differ significantly from that in the 40 per cent light treatment.

Measurements were also taken of the diameter of the stem at the base; number, area and dry weight of leaves; and depth of root penetration. The soil of Markham Oak nursery is derived from Gault Clay, with a thin veneer of Plateau Gravel; and the depth of penetration of the clay by the roots of the two-year-old seedling oaks was often astonishing. The depth was greatest in the seedlings grown in the open, some of the more vigorous of which descended more than three feet. As regards the form of the stems the more profuse branching in the full and 40 per cent light treatments was the most conspicuous feature: even under only 7 per cent of light the main stem showed no discernible deviation from the vertical.

Oak mildew (*Microsphaera alphitoides*) was prevalent in both years, and threatened to be troublesome until controlled by colloidal sulphur sprays. In September, 1953 caterpillars of a sawfly (*Caliroa annulipes*) appeared in large numbers on some of the seedlings in the open and lightly shaded treatments; but their depredations did not affect the samples assessed.

Rhododendron ponticum

A preliminary report on this important forest weed was published in the *Quarterly Journal of Forestry* for October, 1953. It soon became clear that, whereas the shrub grows vigorously in light shade, the heavy shade of young stands of such trees as Douglas fir, silver fir and hemlock is unfavourable to seedling establishment and survival and further evidence was sought on this aspect of rhododendron ecology. Seeds germinated in pots in open woodland were grown through 1953 in a series of five light intensities, ranging from full daylight to less than 1 per cent of daylight and were assessed in the autumn. In the darkest treatment, which would correspond approximately with the conditions of a young stand of Douglas fir, growth, as measured by leaf number, leaf size and dry weight of plant, was greatly reduced: but fungal attack in September so depleted the pots that accurate data could not be obtained. Significant reductions of dry weight were also recorded at relative light intensities of 5 per cent and 10 to 12 per cent, but the reduction of leaf size and area was small in the latter treatment. Seedlings grown in 40 per cent of full light had, on the average, larger, but rather fewer, leaves than those in full light. Their mean dry weight was also somewhat greater, but the difference was scarcely significant. It is suspected that this improved growth and vigour of rhododendron seedlings under moderate shade is due to the favourable microclimate (higher humidity, reduction of wind). On open ground seedlings are very rarely found except in the lee of trees or shrubs, or on the sides of ditches. This experiment will be repeated, with some refinements, in 1954, concurrently with further field observations on the shade tolerance of rhododendron seedlings and young bushes.

Evaluation of Climate for Tree Growth

As a measure of climatic variation in Britain a preliminary trial of the climatic index formulated by C. W. Thornthwaite (1) in America, was undertaken, and its validity was tested against many records of the performance of young and middle-aged stands of Sitka spruce. It was soon clear, however, that differences in soil and topography had usually an overriding influence. Some attention has since been given to the formula for calculating natural evaporation elaborated by H. L. Penman (2) at Rothamsted: this appears to possess an advantage for British conditions over the Thornthwaite formula in taking account of statistics for wind and humidity (where available). It is becoming clear, however, that no attempt to make practical use of a broad climatic classification such as these, which does not also pay close attention to the effect of relief in our hill lands, will be very fruitful. Nor can the modifying influence of soil factors be neglected.

REFERENCES

THORNTHWAITE, C. W. 1948. An approach towards a rational classification of climate. *Geographical Review* 38 (pp. 55-94).

PENMAN, H. L. 1950. Evaporation over the British Isles. *Quarterly Journal of the Royal Meteorological Society* 76 (pp. 372-383).

POPLARS

By T. R. PEACE, *Forest Pathologist* and

J. JOBLING, *Assistant Silviculturist*

Silvicultural Experiments

Eight experiments were laid down during the winter, of which five were concerned with the establishment of different age-types of plant. Two of the remaining experiments, on the spacing of poplars in plantations and on the handling of planting stock, supplement the previous year's work, but were planted on different sites using other varieties. The eighth experiment, concerns the control of weed growth in young plantations.

Mulch and cultivation treatments were maintained in the establishment experiments during the growing season, and applications of fertiliser were made in July and August to the manurial experiment planted in Forest Year 1953. Trees planted in Forest Year 1951 were lightly pruned for the first time in August. Until more is known of the pruning of poplars at the time of planting, trees in silvicultural experiments will not be pruned until at least the third season, when the lower crown will normally be thinned. All field experiments were assessed for height growth at the end of the season.

Work in the nursery has again been concerned mainly with the raising of plantable one-year rooted cuttings, and in addition to continuing the spacing and root pruning experiments at Kennington, similar projects have now been started at Alice Holt (Allotments) and Fen Row nurseries. The manurial investigations, comparing the effect of compost and artificial fertilisers on growth in the cutting lines, have been continued at Alice Holt and Dean Barn (Queen Elizabeth Forest) nurseries, whilst an experiment has been laid down at Harling Nursery in Thetford Forest to determine the most satisfactory manurial treatment for raising cuttings in a basic fen peat soil acutely deficient in potash.

Poplar Trial Plots

Three new trial areas were started, one at Flaxley in the Forest of Dean, one at Wynyard in Durham, and the third at Mundford, Thetford Forest, Norfolk; two of the older trial areas were completed. There are now sixteeh trial areas in England, four in Scotland, and two in Wales.

Populetum

The first major planting was made during the winter. Nearly ninety clones were put in, bringing the total to nearly one hundred. The populetum is designed to hold over three hundred clones. It is being laid out so as to bring closely related poplars as near together as possible.

FOREST GENETICS

By J. D. MATTHEWS, *Forest Geneticist*

Survey of Seed Sources

The location of suitable seed sources for current and future planting programmes continued during the year. The survey of Scotland covering all species in common use was extended to include woodlands and plantations in Argyllshire, Dunbartonshire, Stirlingshire, Renfrewshire and the western parts of Perthshire.

One hundred and thirty-three woodlands and plantations were assessed and classified as suitable or unsuitable for seed collection. The total area of "plus" and "normal" seed sources in the counties mentioned above (i.e. in the West Conservancy of Scotland) amounts to 839 acres at present. Scots pine and Douglas fir seed sources account for half, and European larch, Japanese larch and *Thuja plicata* seed sources for one-quarter of the total area.

The Selection of "Plus" Trees for Breeding

The selection and propagation of outstanding phenotypes ("plus" trees) for use in producing new strains or new hybrids of the major species continued. The total number of "plus" trees of all species which have been marked and recorded is now one thousand and forty-eight.

The Testing of "Plus" Trees

Graftings and rooted cuttings are being raised for trials of the genotype (or tree displays) on representative forest sites in various part of Britain. The planting of these tree displays has begun on a small scale but will be increased during the next two or three years as the graftings made in past years develop and strong scion wood becomes available for further propagation. Two tree displays (one of oak and one of beech) have been established by grafting scions from selected trees on to rootstocks in existing young plantations in the forest.

The raising of plants for progeny trials continued. Seed from ninety "plus" trees of Scots pine and twenty "plus" trees of European larch was sown at Alice Holt. This seed was collected from "plus" trees blown down in Scotland during the gale of January 1953.

Breeding

The establishment of small seed orchards for the production of the "Altyre" (Morayshire) and "Crathes" (Aberdeenshire) origins of Scots pine, and of the "Scone" (Perthshire) origin of Douglas fir continued at Drumtochty forest, Kincardineshire during the year.

A seed orchard for the production of the F_1 hybrid larch (*Larix* x. *eurolepis* Henry) was formed by grafting at Mabie forest, Dumfries-shire. The rootstocks were planted on the site during the winter of 1953. The scions originated from twenty-four "plus" parent trees—twelve European larches and twelve Japanese larches—and the grafting was completed during March 1954. An experimental larch seed orchard was also established on a woodland site in Grizedale Forest, Lancashire.

A small seed plantation, containing selected plants of *Pinus contorta* Douglas and *Pinus banksiana* Lamb., flowered well during the spring of 1953. It is expected that seed of the hybrid pine *P. banksiana* ♂ x *P. contorta* ♀ will be available for sowing in the spring of 1955.

Vegetative Propagation

The final total of grafts made during the spring of 1953 was 9,076, and the total of successful graftings surviving to the spring of 1954 was 4,054, representing 271 parent trees. The majority of these have been retained in the nurseries for a second year before planting out in tree banks, tree displays and seed orchards.

Propagation by cuttings was continued. The benefits of rooting media containing granulated peat and vermiculite were again confirmed for X *Cupressocyparis leylandii* and *Sequoia sempervirens*. Rooted cuttings of the last-named species taken from side branches have assumed an upright habit after being supported by stakes for two full seasons of growth. At present staking appears to be the best method of overcoming the prostrate tendency of such cuttings.

Flowering and Fruit Production

Mr. Mitchell has again made phenological observations on individual trees growing in the neighbourhood of Alice Holt. A summary of five years of general observations on flowering and fruit production made in many parts of Britain is given elsewhere in this Report (see page 64).

Further details of progress during the year are now given by species.

Beech

The number of plus trees which have been selected, marked and recorded is now fifty-two. Forty-eight of these have been propagated by grafting. Three very fine trees were found at Amberley Court, near Stroud, Gloucestershire.

A detailed study of the flowering and mast production of beech in Southern England during the thirty years 1921-1950 confirmed the generally accepted relationship between summer weather conditions and the size of the beech mast of the following year.

European Larch

Sixty-five acres of plantations were added to the classified list of European larch seed sources. The majority of the seed sources located so far are in North Eastern Scotland.

The characteristics looked for in plus trees of European larch are vigorous growth in girth and height, straightness and persistence of stem, narrow to intermediate width of crown, good mass of foliage, relatively small branches with flattened angle of branching, freedom from the dieback of larch and from visible stem cankers, and reputation for good timber quality.

Clones of such trees are being formed by grafting. The first grafts are to be placed in one or more collections (or tree banks) which will eventually contain about 750 clones of various origins.

Two hundred and twenty-one plus trees have been selected, thirty-five having been found in the West Conservancy of Scotland during the past summer.

Sixty-one plus trees were propagated during the spring of 1954, bringing the total number of clones formed to over one hundred. The discovery of two larches at Epsom, Surrey, probably dating from 1713 and 1718, provided further information about the early introduction of European larch.

Two small trials of the genotype of selected plus trees were planted in 1951 and 1952. Future tree displays will be on a larger scale and on six representative sites in various parts of Britain.

Intra- and inter-specific hybridization was begun on a small scale during the spring of 1954. This work will be extended with the emphasis at first on hybrids between European and Japanese larch. Inbred lines of European larch are to be started for crossing with inbred lines of Japanese larch.

Most of the grafting is now done in the open. Fifteen hundred grafts of European larch were made during February and March 1954. A small trial of propagation by layering was begun at Grizedale.

Japanese Larch

The total area of classified seed sources is now 185 acres, fifty-three acres being suitable for treatment and use as seed stands.

The search for plus trees of Japanese larch has shown that while few trees can compare with the best European larch, there are some very fine stems in the older plantations. Plus trees of Japanese larch must be vigorous and healthy, and special emphasis is placed upon straightness and circularity of the stem and compactness of crown. Thirteen plus trees were selected in the West Conservancy of Scotland, bringing the total so far to fifty-six. Scions were collected from twenty-one plus trees during the spring of 1954. The number of clones to be included in the tree banks is 250.

As with European larch, small-scale intra- and inter-specific hybridization was carried out in the spring of 1954.

Studies of methods of propagating Japanese and hybrid larch from summer-wood cuttings continued. The number of cuttings rooted was again low, principally due to *Botrytis* attack. A new propagation frame has been completed which incorporates sub-irrigation (in which the water is carried to the rooting medium by means of glass wool wicks) and electrical soil warming. This frame will be used for further studies of the rooting of cuttings of the larches, and also of the pines and spruces.

The effects of various methods of shoot pruning on the flowering and fruit production of eight-year-old Japanese larch are being compared at Alice Holt.

Scots Pine

Scions were collected from plus trees following the gale of January 31st 1953 in North East Scotland. Grafting began in the open on March 16th 1953, at four centres, and continued until the end of May. The majority of the plus trees propagated were from ten plus stands in the Dee Valley and Morayshire—each plantation being represented by at least fifteen and usually by over twenty clones. As the graftings develop each clone from all sources will be represented in a central collection (or tree bank) of Eastern Scottish Scots pine and used for breeding of improved strains of this species. In addition, and as a short-term project, each plus stand will be represented by a seed orchard, so that seed of the best origins lost in the gale will again be available as soon as possible.

Douglas Fir

Eleven fine plantations of Douglas fir were located during the survey of seed sources in Argyllshire (Inveraray Estate, Barcaldine Forest, Benmore Forest and Stonefield Estate), Stirlingshire (Touch Estate), and in Perthshire (Lanrick and Strathallan Estates). The vigour and quality of these plantations confirmed the existence of good strains of Douglas fir in Scotland—that associated with the Scone Estate, Perthshire, being one of the best.

STUDIES OF GROWTH AND YIELD

By Dr. F. C. HUMMEL, *Mensuration Officer*

DURING the past year, 47 new sample plots were established and 112 were re-measured; one plot was lost through wind blow. Table 7 summarises these details by countries.

Table 7

SAMPLE PLOTS IN GREAT BRITAIN, 1954

	England	Scotland	Wales	Total
Plots in being, 1st April, 1953	261	201	87	549
Plots established, 1.4.53.—31.3.54	33	14	—	47
Plots written off (blown, felled etc.)....	1	—	—	1
Plots in being 31st March, 1954	293	215	87	595
Plots remeasured 1.4.53 to 31.3.53	40	72	—	112

Of the new plots established in England, 14 were in hardwoods, the remaining 19 were in coniferous species, mainly in areas where there had been no previous sample plots. In Scotland, 14 new plots were established, all in coniferous species. Three of the conifer plots in England, and four in Scotland were established in silvicultural spacing experiments. A separate note is included in this report on page 127 on the two Douglas fir sample plots at Tortworth which were first measured in 1912.

Revised Yield Tables for Conifers in Great Britain were published as Forest Record No. 24 (H.M.S.O., 1s. 3d.); and a *Volume Table for Small Hardwood Trees* was issued as Forest Record No. 28 (H.M.S.O., 9d.).

Two new instruments were tested during the year. The prototype dendrometer referred to in previous annual reports, has been tested on individual trees, but has not yet undergone full-scale tests under forest conditions. Results so far have proved satisfactory and indicate that with one or two minor modifications it will meet our requirements for sample plot work, thus eliminating the need to climb large sample trees. The other instrument tested was Bitterlich's "Tariff-messwinkel" which is very light and easy to handle, and has the advantage over conventional calipers that basal areas and volumes for individual trees may be read, as well as diameters. The instrument has been re-calibrated to give British units of measurement.

The statistical work undertaken for the other sections of the Research Branch has increased both in volume and in scope. In addition to the design and analysis of experiments and the design of several sampling schemes, some special investigations have been carried out. One of these, on the relationship between the number of "usable" seedlings and the mean height of the seedlings is briefly described on page 101 of this report.

The Mensuration Section has co-operated with the Deputy Surveyor of the Forest of Dean and the School of Forestry at Oxford University in an enumeration project which is still in progress. Other special projects have included production forecasts for specific areas mainly in Scotland; an investigation for the Utilization Development Section into the volume and yield of oak scrub;

and the supply of material from permanent sample plots and other sites, for strength tests at the Forest Products Research Laboratory at Princes Risborough, and for density tests at the Imperial Forestry Institute at Oxford.

As was reported last year, work has commenced on the revision of the 1947-49 Census of Woodlands. This work is being done on a county basis and the counties of Rutland, Huntingdon and Kincardineshire, on which work had commenced in December, 1952 and January, 1953 respectively, were completed, as were the counties of Cambridge, Hereford and Angus. The re-survey of Berkshire and Flint is now in progress. A separate note on page 136 of this report discusses the present character of the woodlands in Huntingdonshire and some of the changes which have taken place in recent years.

FOREST PATHOLOGY

By T. R. PEACE, *Forest Pathologist*

Conifer Diseases

Group Dying of Spruce. The fungus *Rhizina inflata* was observed fruiting in great quantity in many of the latest dieback groups. Attemps to bring the fungus into culture were unsuccessful, but a small inoculation experiment using crushed fructifications was laid down. A diseased area at Chepstow was cleared and planted with a variety of species to test possible after-effects on a second crop. Root lesions were found to be a constant feature of all affected trees examined.

Top Dying of Norway Spruce. Several more outbreaks of this disease were visited. All the affected stands had histories of neglect and underthinning, but this may not be significant.

Dieback of Picea omorika at Bedgebury. Inoculations using *Rhizosphaera pini*, the most commonly occurring fungus on the needles of affected trees, proved negative. A trial of lime and phosphate was laid down at Bedgebury to see whether a breakdown in the humus layer or addition of phosphate would check the dieback.

Resin Bleeding of Douglas Fir. Several new outbreaks of this possibly rather serious disease were reported. It causes general deterioration of the crown and sometimes death. Material was collected from most of the outbreaks for culturing and detailed examination. The first signs of the disease appear to be small lesions in the bark, often, but not always, at the base of branches. Two fungi, a *Cephalosporium* and a *Myxosporium*, have appeared fairly consistently in culture. Inoculation experiments with them are in progress.

Melampsora pinitorqua. A test area of aspens and two-needled pines has been planted at Alice Holt. This will be used later for assessing the resistance of various pines and aspens to this disease. *Populus grandidentata* and *Pinus resinosa*, both being tested at the request of the Ontario Forest Service, were successfully established in a naturally infected area at Willingham Forest near Lincoln.

Keithia thujina. Observations on the isolated *Keithia*-free nurseries were continued. None became infected during the year.

Cronartium ribicola. Propagation by grafting of the resistant *Pinus strobus*, received from America, was continued. It is hoped to raise enough to form a seed orchard. A test area of currants and infected *Pinus strobus* has been started at Alice Holt. Eventually this will be used for testing the seed progeny of the American resistant clones.

Botrytis cinerea on Nursery Conifers. Douglas fir and Sitka spruce seedlings were successfully infected with *Botrytis cinerea*, after being covered with a hessian shelter for periods of one week and three weeks and then being sprayed with a spore suspension. Douglas fir proved more susceptible than Sitka spruce. This technique will be used to get infected plants in experiments, which have been laid down at Wareham and Alice Holt, on spraying *Botrytis* with a range of fungicides.

Damping-off of Conifers. Tests of seed dressings, carried out in the spring of 1953, on Sitka spruce and Scots pine, were somewhat inconclusive, owing to mouse damage. But a few substances definitely toxic to trees were eliminated and a repeat experiment protected against mice is now in progress.

Hardwood Diseases

Nectria Canker of Beech. The fungus *Nectria ditissima* was consistently isolated from cankers. Artificial inoculation of potted plants failed. Efforts are being made to find how the infection occurs in the forest, and in one case *Nectria* infection has been found to follow weevil attack on the current year's shoots. A survey was made of Westbury Forest, Hampshire, where the disease occurs very seriously, in an effort to correlate severity of attack with crop or site factors.

Beech Bark Disease. Collection of site data was continued. One or more of the three factors, shallow soil, old age of the crop, and neglected thinning, were found to be present in each case.

Bacterial Canker of Poplars. About 1,500 plants of 160 clones were inoculated in the spring of 1953. Results of these inoculations will not be available until the summer of 1954. Inoculations made in 1952 were assessed and yielded valuable results. A further 2,000 cuttings have been planted for inoculation in May 1954. Fairly consistent results are emerging from these annual inoculations.

A few of the trees in most of the trial plot areas were inoculated in the spring of 1953. It is hoped that when the disease develops, it will provide a test of natural infection on the remaining uninoculated trees.

Sooty Bark Disease of Sycamore (Cryptostroma corticale). See also Report by Dr. Robertson (page 57). A survey was carried out in the summer of 1953 of areas already known to be affected. It was found, generally, that the disease was tending to die out, rather than to increase. Its virulence in the summers of 1948-1950 remains unexplained.

Diseases of Chestnut. At the end of the year the Forest Pathologist was able to see in Italy and Switzerland the progress made by Chestnut Blight (*Endothia parasitica*), and the interesting, but so far unexplained, phenomenon of acquired resistance.

A locally serious attack on coppice chestnut by the normally harmless fungus *Cryptodiaporthe castaneae* was found in Bramshill Forest. But it is suspected that bad growing conditions may underly the trouble.

Elm Disease (Ceratostomella ulmi). Grafting material from a number of resistant selections was received from Holland. These are mainly trees which have shown a high degree of resistance to inoculation, but not quite enough to justify their public issue. As an aid both to ourselves and to the Dutch authorities these will be tested under conditions of heavy natural infection, in the hope that some of them may turn out to be sufficiently resistant in practice, to be put into general use in Holland and subsequently here.

Wound Protectants. Tests of various bituminous paints, as dressings for pruning wounds on hardwoods, have been set up in Buriton Forest on beech and lime. So far results are only available of initial points like applicability.

Miscellaneous Activities

Plant Quarantine. A good deal of work has gone into the consideration of quarantine measures, with especial reference to the danger from Chestnut Blight.

Visits. In October 1953 a short visit was paid to Belgium, in company with representatives of the Ministry of Agriculture, and at the invitation of the Belgian Government. Quarantine matters were discussed, and visits paid to Research stations, nurseries, etc.

FOREST ENTOMOLOGY

By Dr. MYLES CROOKE, *Forest Entomologist*

Two major projects, relating respectively to *Bupalus piniarius* L. and to forest insect development in the Scottish gale damaged woodlands, occupied most of the section's time and are reported upon in detail in Section IV of this *Report* (see pages 158 and 163).

The sawfly survey was continued, as in previous years, and covered the same forest areas in Wales, northwest England, and south and east Scotland. The group of small larch sawflies, the most important of which are *Anoplonyx destructor* Bens. and *Pristiphora laricis* Htg., was again found to be widespread, but the density of population remained low in most areas and showed a slight recession when compared with the figures for 1952. Even more marked was the decrease in numbers of the large larch sawfly, *Pristiphora erichsoni* Htg., which was almost everywhere less numerous than in 1952. At Auchenroddan Forest (Dumfriesshire), where the highest density ever recorded by the survey since its inception in 1949 was reported in 1952, a decrease of approximately 50 per cent took place, and appeared to be associated with the presence of a polyhedral disease of the larvae. Coupled with the survey, laboratory work continued on the biology of the sawfly species associated with larch, spruce, and pine crops. The final unidentified species in the complex of small larch sawflies was shown to be a new species, although very closely related to *Pristiphora wesmaeli* Tisch., and it was designated *P. glauca* Bens.

An experiment to test the effectiveness of applying insecticidal dusts to newly planted Scots pine to ward off *Hylobius abietis* L. attack was conducted at Midmar Forest (Aberdeenshire) where the chemicals used were:

(1) A cotton dust containing 3% BHC plus 10% DDT.
(2) A cotton dust containing 3% BHC plus 5% DDT.
(3) 10% DDT.
(4) 20% crude BHC (=2½% BHC).
(5) 10% crude BHC (=1¼% BHC).

Treatment was made in late April, when each plant received one ounce of the appropriate insecticide which was applied to the stem and to the surrounding soil and vegetation. The weevil attack was not as severe as had been anticipated, due in part to a summer unfavourable to weevil activity, and only slightly more than 50 per cent of the trees in the untreated controls had been attacked by the end of the season. Both cotton dusts significantly reduced the level of attack but neither of the crude BHC dusts or DDT gave satisfactory protection.

UTILISATION DEVELOPMENT

By E. G. RICHARDS, *Utilisation Development Officer*

THE Advisory Committee on the Utilisation of Home-Grown Timber recommended that, following the work already carried out on hazel, investigations should be made into the possibilities of pulping other hardwood species, and that work should commence on the possibility of extracting commercially useful substances from bark and wood. Projects concerning problems of marketing small-sized thinnings and scrub were continued. These included inquiries into the pulp industry, river and sea defence in England and Wales, and the design of a building, to serve as an office, in timber obtained from thinnings.

Portable Chipping Machines

Trials were made with a type of portable chipping machine new to Great Britain. Material up to seven inches in diameter, comprising scrub oak and birch poles, untrimmed hazel coppice, and thinnings of pine, larch and spruce, was successfully chipped. In the United States, chips produced by the same process are used for deep-litter systems of poultry keeping, as animal bedding, horticultural mulches and for pulp production.

Preliminary investigations have shown that though limited marketing possibilities do exist at home, in nearly all cases the acceptance by consumers of this new material may be less ready than in the United States.

Thinning House

A two-roomed office of an experimental design, developed in co-operation with the Timber Development Association and made mainly from small-sized home-grown timber, is being erected during the forest year 1954. It is being constructed largely from panels, each consisting of a series of interlocking strips made up from the following species: Sitka spruce, Norway spruce, Scots pine, Corsican pine, European larch, Japanese larch and Douglas fir, the bulk of which were cut from thinnings under six inches top diameter over bark. The framework, flooring and joinery timber will be cut from thinnings or from mature timber of sawmill size. The primary conversion and grading of the wood was carried out during the year.

Forest Produce in River and Sea Defence

With a view to ascertaining the demand for timber, in river and sea defence work all the river board and river conservancy engineers were visited, and a questionnaire was sent to all local authorities responsible for any length of coast. The enquiry was not extended to Scotland because the problems of river and sea defence there are small compared with those of England and Wales, and the present annual consumption of forest produce is not great.

The survey revealed that in England and Wales about 300,000 cubic feet of timber (home-grown and imported) and about 270,000 bundles of faggots (mainly willow and sweet chestnut) are consumed annually, far more being used on the South and East coasts of England than in any other area.

In collaboration with the Kent River Board an experimental permeable groyne was erected near Rye. Unpeeled poles of the major coniferous species have been arranged vertically between sawn timber walings. It is hoped to obtain some indication as to which will be the most suitable species for this type of work.

During the enquiry several encouraging service records came to light; for example, revetments of larch planking and round stakes used in river defence in the Lake District were found to be still sound after more than twenty years service.

Pulpwood and Fibreboard Industries

The timber requirements of the paper pulp industry in Great Britain were ascertained. About 11½ million hoppus feet of round timber are used annually for paper pulp production, but less than one million hoppus feet of this is home-grown. However, home-grown timber, especially the spruces, is quite suitable, if prepared to the paper manufacturers' specifications.

In fibreboard production, some 2 million hoppus feet of timber are used annually; practically all of this is home-grown. The bulk of the material is from small coniferous thinnings of species other than larch—which is said to be too resinous—but certain hardwoods such as poplar and willow are also used regularly.

Coppice and Scrub

Co-operation with the Rural Industries Bureau continued throughout the year, and the underwood survey was completed. The Textile Department of the Manchester College of Technology have agreed to make samples of paper from unbarked hazel coppice.

Wood Waste

Discussions have been held with Mr. W. C. Ibbett, a Horticultural Advisory Officer of the Ministry of Agriculture and Fisheries, concerning the use of sawdust as a mulch or as a compost. His experiments so far suggest that when sawdust is used as a deep litter medium in poultry keeping, the residual mixture of poultry droppings and sawdust makes an excellent compost for many types of horticultural crops.

Tanbark

Samples of bark were analysed by the British Leather Manufacturers Research Association with a view to assessing their tannin content and determining their suitability for leather manufacture. Reports so far show that western hemlock, Sitka spruce and Norway spruce bark all have a tannin content of more than 15 per cent of the moisture-free bark, but have certain disadvantages such as undesirable colour. Scots pine and Corsican pine, on the other hand, have a lower tannin content but have a more suitable colour.

MACHINERY RESEARCH

By R. G. SHAW, *Machinery Research Officer*

WITH the completion of a new building it has been possible to concentrate at Alice Holt all experimental machines with the exception of those actually out on field trial. This building provides accommodation for the equipment necessary to complete a large part of the investigations at Alice Holt, and also houses prototypes which may be needed for later review whether in the same or another form.

British Tractors

The problem of finding a tractor design that can deal with very soft ground conditions has been actively pursued and a separate paper on this subject appears in this *Report*. (See page 170.)

Ploughing

The American mounted toolbar is still on trial and there is now a British equivalent. The progress made on this project has been disappointing owing to the inability of these big mounted ploughs to deal with the heavy vegetation so often found in heathland ploughing. The essential close mounting of the plough behind the tractor (to avoid upsetting tractor balance) does not allow space for an adequate coulter and this results in choking.

A tine plough giving deep subsoiling and a comparatively shallow furrow continues to give good results under these severe heathland conditions. For drainage ploughing and for ploughing of easier heathland, standard commercial ploughs are in general use.

Timber Haulage

Investigations into the use of a mounted sledge on a wheeled tractor has shown that this method provides a cheap method of moving small loads over short distances. The drawbar pull required to pull these sledges is, however, very high and this limits the payload to under one ton. Wherever ground conditions permit the use of wheeled trailers or sulkies, their greater payloads result in cheaper transport.

Cableways

One British and two Swiss designs have continued in experimental use during the year. The man-hours absorbed in erecting all three types are far too great for early thinning operations. Attempts are being made to reduce the erection time to ten man-days or less.

Clearance of Derelict Woodland

Several of the grubber blades, mentioned in last year's report, are now in general use; and many of the contractors now undertaking land clearance throughout the country appear to favour these designs.

Winches

A light power-operated winch has been developed for use on inaccessible sites which can not be reached by tractor-mounted winches. This winch has a 350 c.c. air-cooled engine, a centrifugal clutch and 350 ft. of $\frac{5}{16}$ inch cable. It can be carried by two men and conveyed in a van or Land Rover.

Mechanisation of Nursery Operations

Promising results have been obtained in preliminary trials of the Holland Transplanter. This is a self-propelled machine of American origin and it has been used for a large proportion of the lining out during the 1954 season at Bramshill.

Drain Cleaning

No really satisfactory machine has yet been devised for the cleaning of old drains in young plantations. This has been largely due to insufficient space for the operation of a tractor, which has meant that all attempts to solve this problem have been confined to self-propelled machines of small size. If a certain number of young trees can be sacrificed to give access to tractor-mounted drain cleaning machines there may be possibilities in some of those already in commercial use.

LIBRARY, DOCUMENTATION AND PHOTOGRAPH COLLECTION

By G. D. KITCHINGMAN, *Documentation Officer*

Library

THE number of books in the library on the 31st March 1954, was 2,335, an increase of 260 during the year. Loans of books numbered 613. Eighty-five volumes of periodicals were bound, bringing the total to 1,003.

Information Files. This section of the library increases slowly and is now becoming a very valuable collection of typescript reports, separates, etc.

Documentation. Since January, when a Clerical Officer was posted to the library, to take over the routine library work, much more time is being given to documentation; consequently the accumulation of arrears, instead of slowly increasing, is now gradually disappearing. The number of cards in the indexes is now about 53,000, equivalent to about 17,000 references. Lists of references on literature were supplied as required.

Photograph Collection

During the year the number of colour slides and prints in the collection increased from 279 to 1,996, and from 5,359 to 9,819 respectively: a total increase of 6,177.

Great use is now being made of the collection. Enquiries numbered 251, of which 157 were from outside the research station. There were 138 separate orders for photographs, 26 from Alice Holt and 112 from outside. There were 70 applications for loan of slides, 50 of which were to members of the Research Station.

Library Quarterly

Three numbers were issued during the year. The three Library Records issued with it dealt with:

1. Lodgepole pine
2. Japanese larch

and 3. Indexes to British Forestry literature.

Aslib

Close contact is maintained with the Association of Special Libraries and Information Bureaux, of which the library is a member.

Part II. Research undertaken for the Forestry Commission by Workers attached to Universities and other Institutions

NUTRITION PROBLEMS IN FOREST NURSERIES SUMMARY REPORT FOR 1953

By BLANCHE BENZIAN

Rothamsted Experimental Station, Harpenden, Herts.

Introduction

THE experiments described in this report were carried out under the guidance of the late Dr. Crowther and many of the data had been worked up and the results discussed before his untimely death in March 1954.

As was mentioned in the Summary Report for 1952 (see *Ann. Rep. For. Res.*, 1953), it is important that the various experiments are laid down at a number of centres covering a range of soils, and repeated over several seasons, to ensure that any conclusions drawn are not applicable to too narrow a set of conditions. In 1952 two groups of experiments lasting for five years had been brought to a conclusion, and details of the results covering the whole period were presented. As all the main series of experiments existing in 1953 were continued in 1954, no summaries covering long periods are given here. In the following pages it is only possible to draw attention to some features emerging from the work of a single season.

In this report, as in that for 1952, details of experimental design and standard errors have been omitted to simplify the tables.

The 1953 Season

The dry spring of 1953 made it possible to make cultural preparations early, and sowing in all nurseries had been completed by March 25th. The dry rather cold spell continued for several weeks after sowing, and germination was exceptionally slow. At Ampthill it took as long as six weeks. After a slow start growth was good. The rainfall recorded at Rothamsted for the four summer months—May, June, July, August, was a little above the long-period average and was fairly evenly divided between the five growing months. There were no such spells of intense drought in June and July as during the 1952 season. For most of the year the rainfall figures for Wareham and Ringwood were similar, but in June Ringwood had one inch and in July two inches more than Wareham.

Colour symptoms in Sitka spruce caused by various nutrient deficiencies appeared earlier than usual. The "no potash" plots at Ringwood looked reddish in June, whereas generally the plants have a mauvish tinge which does not normally appear before August. Later in the season seedlings without potash showed "autumn" colours ranging from yellow to purple.

In general, growth within the plots was very even, and the experimental errors were low. Early sowing and good growing conditions may have helped, but there is no doubt that the great care taken by the nursery staff to carry out all cultural operations by blocks must have led to a considerable increase in the precision of the experiments.

Manuring of Seedbeds

Forms of Nitrogen

There were good responses to nitrogen in all nurseries, and in several cases the addition of fertilizer nitrogen doubled the size of the plant. Plots without nitrogen could easily be picked out by their pale colour, and many compost plots showed nitrogen deficiency symptoms late in the season.

As nitrogen responses were considerably larger in 1953 than in 1952, there was a better opportunity to study the response of Sitka spruce and other species to ammonium sulphate and "Nitro-Chalk" under low pH and high pH conditions. A comparison between "Nitro-Chalk" and ammonium sulphate had been introduced into the two pH range experiments at Wareham and Kennington Extension in 1951. (The design of these experiments has been described in the *Annual Report on Forest Research*, 1953.

NITROGEN FORMS IN pH RANGE EXPERIMENTS ON ONE-YEAR SEEDLINGS OF SIX SPECIES SOWN IN DRILLS

Table 8

	pH in:		*Height in inches* 1953, averaging medium lime and high lime					
	H_2O	0.01M $CaCl_2$	Tsuga het.	Sitka spruce	Pinus contorta	Douglas fir	Japanese larch	Ash
Wareham								
No nitrogen	6.5	6.0	0.8	1.2	1.8	4.6	3.7	failed
"Nitro-Chalk"	6.4	6.0	1.3	1.5	1.7	4.9	4.3	
Amm. sulphate	6.0	5.4	1.8	2.2	1.9	5.5	5.2	
Kennington Extension								
No nitrogen	6.8	6.3	0.8	1.2	1.9	5.0	6.2	4.0
"Nitro-Chalk"	6.7	6.4	0.9	1.5	1.8	5.7	6.5	5.2
Amm. sulphate	6.5	6.1	1.4	1.8	2.1	5.7	7.3	4.5

On plots which had been either acidified, remained untreated, or had received a small amount of lime, the differences between ammonium sulphate and "Nitro-Chalk" were small and irregular; but on plots with medium and high lime applications (see Table 8) ammonium sulphate was superior to "Nitro-Chalk" at both centres for all conifers, except Douglas fir at Kennington Extension. These results show once again that the species of conifers tested grow better with ammonium sulphate than with "Nitro-Chalk". On the other hand, ash plants on the "Nitro-Chalk" plots at Kennington Extension were 0.75 inches taller than on the ammonium sulphate plots. The ash failed at Wareham.

Hitherto in this experiment ammonium sulphate had been compared with "Nitro-Chalk", a mixture of ammonium nitrate and calcium carbonate. ("Nitro-Chalk" had been chosen as a commercial material convenient as a topdressing in acid nurseries, and had been used for many years as part of our standard fertilizer dressings). To compare the effects of ammonium nitrogen and nitrate nitrogen it is advisable to test some nitrate other than ammonium nitrate, and in the 1954 season the "no nitrogen" treatment in the pH range experiments has been replaced by calcium nitrate. This will, in time, provide a test on ammonium nitrogen, nitrate nitrogen and a compound including both.

Other comparisons of forms of nitrogen with and without formalin were started in 1952 at four neutral or slightly acid nurseries (Ampthill, Old Kennington, Ringwood and Kennington Extension) and without formalin, at two acid nurseries (Bagley and Wareham). The forms of nitrogen tested were the three soluble fertilizers—ammonium sulphate, "Nitro-Chalk" and calcium nitrate and, in addition, the slowly acting plastic waste, formalised casein. The soluble forms of nitrogen were applied in two topdressings, each of 4.5g. N per sq. yd., one at the end of June and the other early in August, whereas formalised casein at 9 g. per square yard was dug in together with the standard PK fertilizer a few weeks before sowing.

EXPERIMENT TESTING FORMS OF NITROGEN MANURING OF SITKA SPRUCE ONE-YEAR SEEDLINGS, 1953

Table 9

	Four neutral or moderately acid soils			Two very acid soils	
	pH in 0.01M $CaCl_2$	Height in inches: Without formalin	Height in inches: With formalin	pH in 0.01M $CaCl_2$	Height in inches: Without formalin
No nitrogen	5.3	0.9	1.6	4.0	1.6
Calcium nitrate	5.3	1.2	2.3	3.9	2.6
"Nitro-Chalk"	5.2	1.4	2.5	4.0	2.5
Ammonium sulphate	4.9	1.6	2.3	3.6	2.4
Formalised casein	5.1	1.6	2.6	3.8	2.9

Table 9 shows that growth was generally poor without formalin at the high pH nurseries, but where formalin was given the seedlings were as good as those on the two acid nurseries. On the four neutral or moderately acid soils without formalin, ammonium sulphate was significantly better than calcium nitrate in three cases out of four, and "Nitro-Chalk" was intermediate in every case. There were no real differences between the forms of soluble nitrogen at the very acid nurseries (without formalin) or at the four others where formalin had been applied. Quite early in the season the plots that had received formalised casein stood out clearly in the two acid nurseries, and they maintained their superiority until the autumn. On plots that had not received formalin, plant numbers were reduced by formalised casein at the two neutral centres, Ampthill and Old Kennington.

Phosphorus and Potassium

Height responses to phosphorus tend to be very consistent from year to year, but even on very phosphate-deficient soils colour symptoms on "no phosphate" plots have rarely been observed. The rates of dressing in acid nurseries in all those experiments that receive a standard fertilizer application are 4.5g. P and 9g. K per square yard, forked into the soil a few weeks before sowing. In a series of experiments at four centres phosphorus and potassium were tested at two rates, namely 3 and 6g. P and 6 and 12g. K per square yard. These rates straddle the amounts used as standard fertilizer dressing in our nursery experiments. At all four centres, doubling the phosphate application increased the height of the seedlings, and in three of the four experiments the increase was highly significant. Doubling the potassium had no effect on height. If similar results are obtained in this and an additional series of experiments carried out in 1954, the relative amounts of phosphate and potassium to be used may have to be reviewed.

Magnesium

Magnesium in the form of either magnesium sulphate or dolomite was tested in several series of experiments started in 1952. Again there were clear-cut differences in colour symptoms ("hard yellows") between plots with and without magnesium at both Bagley and Ringwood, but with the possible exception of the sulphate of ammonia plots in one experiment at Ringwood there were no height differences due to magnesium. At Ringwood a visual score on a scale of 1 to 10 was taken. The results are shown in Table 10.

YELLOW DISCOLORATION IN ONE-YEAR SITKA SPRUCE SEEDLINGS ASSOCIATED WITH MAGNESIUM DEFICIENCY

Table 10

	Mean score per plot for "hard yellows"		
	Plot R 52	Plot R 54	Plot R 53
No magnesium	3.4	6.2	2.4
Magnesium sulphate	0.4	0.8	0.9
Dolomite residues	—	1.1	0.6
Both forms of magnesium	—	—	0.4
Compost	—	—	0.0

In 1953 the rate of magnesium application was changed from 4.5gm. to 1.5gm. per square yard. Although this rate was enough to reduce the colour symptoms considerably, it was not sufficient to eliminate them entirely, and in 1954 the rate has been increased to 3gm. "Hard yellows" have hardly ever been observed on plots that have received the standard dressing of 10 lb. of bracken and hopwaste compost. Formalin often reduces the colour symptoms.

Effect of salt concentration on Sitka seedlings

The germinating seedlings of conifers are said to be very sensitive to high salt concentration and a method of reducing the salt concentration in seedbeds was tested in experiments at Ringwood and Kennington Extension. Phosphate, potassium and magnesium were applied at two rates as a low salt fertilizer in the form of dimagnesium phosphate, together with potassium sulphate and compared with the same rates of nutrients supplied by the standard compound fertilizer of potassic superphosphate and magnesium sulphate. Despite very dry conditions during germination, when damage from high salt concentrations might have been expected to show, there was no benefit from the low salt fertilizer over the standard form, either in seedling height or in plant number.

Manuring of transplant lines

In 1953 an experiment was laid down at Wareham to test, both in the presence and absence of a basal NPK fertilizer, the responses to nitrogen, phosphorus and potassium applied at the same rates as in the basal fertilizer. In other words, each of the nutrients was tested at two levels. These straddled the standard rates of 6gm. N, 4.5gm. P and 9gm. K per square yard. The results are shown in Table 11. The transplants cover a wide range of sizes; 8 to 15½ inches. In the absence of a basal fertilizer there are large responses to nitrogen and phosphate and also to potassium in the presence of nitrogen. Where a basal fertilizer had been applied the plants benefited from extra nitrogen, but there were no further responses to P or K.

HEIGHT IN INCHES OF ONE-PLUS-ONE SITKA SPRUCE TRANSPLANTS AT WAREHAM (W 80), 1953

Table 11

	Averaging with and without potassium			
	No nitrogen No phosphorus	Nitrogen	Phosphorus	Nitrogen +Phosphorus
No basal fertilizer	8.0	12.5	9.8	13.2
With basal fertilizer	13.6	15.3	13.5	15.4
	Averaging with and without phosphorus			
	No nitrogen No potassium	Nitrogen	Potassium	Nitrogen + Potassium
No basal fertilizer	9.0	12.0	8.9	13.7
With basal fertilizer	13.7	15.1	13.4	15.6

Bracken and hopwaste compost: 10.0.

Potassium and Magnesium Deficiency Colour Symptoms

In transplants it is not easy to distinguish at the end of the season between potassium and magnesium deficiency symptoms. Shortage of potash tends to show itself first by a mauve tint appearing on needles of all parts of the plant during August and September. Later in the season bright yellow colours often develop which seem to be indistinguishable from the yellow discoloration normally associated with magnesium deficiency.

NUMBER OF ONE-PLUS-ONE SITKA SPRUCE TRANSPLANTS SHOWING YELLOW DISCOLORATION AS PER CENT OF TOTAL NUMBER OF PLANTS PER PLOT IN NOVEMBER 1953 AT RINGWOOD (R 47)

Table 12

	Mean of no formalin and formalin			
	No potassium No magnesium	Potassium	Magnesium	Potassium +Magnesium
"Nitro-Chalk"	8	5	2	0
Ammonium sulphate	43	16	0	0

Table 12 shows the percentage of plants exhibiting this yellow discoloration in November in a Ringwood experiment comparing topdressings of "Nitro-Chalk" and ammonium sulphate, in factorial combination with tests on potassium, magnesium and formalin. The symptoms are developed much more acutely on the ammonium sulphate than on the "Nitro-Chalk" plots. Both potassium and magnesium reduce the yellow discoloration. One other interesting feature frequently observed before is the improvement of the colour by formalin.

Needle-Tip Burn in Seedlings and Transplants at Wareham

The symptoms of "needle-tip burn" mentioned in *Ann. Rep. For. Res.* for 1953 were again recorded from several experiments at Wareham. As in previous years the symptoms on seedlings were first observed after a sudden hot spell. In a seedbed experiment testing compost and fertilizers in the fourth season, the symptoms appeared on the compost as well as on the fertilizer plots, though to a lesser degree. In previous years the symptoms had only been observed on fertilizer plots. In a transplant experiment needle-tip burn was absent from plots that had received only compost, but appeared both on plots treated with fertilizer alone, or with compost and fertilizer together. In the rest of the nursery the symptoms were almost completely confined to fertilizer plots. The damage was worse on ammonium sulphate than on "Nitro-Chalk" plots, and high nitrogen appeared to aggravate the condition.

Several batches of plants suffering from tip-burn were examined mycologically. Although in nearly all cases they showed some secondary infection, the cause of the symptoms is more likely to be a nutritional disorder—perhaps a minor element deficiency or damage due to high salt concentration.

Long-term Rotation Experiments at Wareham and Kennington

The design and purpose of these experiments was described in detail in *Ann. Rep. For. Res.*, 1953. In 1953 all phases of the rotation were represented for the first time. The results of the rotation experiments and the associated continuous manuring experiments are given in Table 13.

RESULTS OF ROTATION AND CONTINUOUS SITKA SPRUCE MANURING EXPERIMENTS AT KENNINGTON AND WAREHAM, 1953

(Third-year results for W and KT 101, 102, 104/5)

Table 13 (First-year results for W and KT 106/7)

Rotation Experiments

	1+0 Seedlings				1+1 Transplants	
	Kennington		Wareham		Kennington	Wareham
	KT 102 First crop	KT 101 Second crop	W 102 First crop	W 101 Second crop	KT 102 First crop	W 102 First crop
	Height in inches					
After:						
Bare fallow	3.2	3.5	2.4	2.7	14.2	10.1
Lupins	2.5	3.3	2.3	2.8	13.6	9.8
Rye	3.0	3.4	2.5	2.6	13.7	11.2
Ryegrass	2.9	3.2	2.4	2.4	13.6	11.7
S.S. seedlings	2.8	3.3	2.9	2.6	14.6	9.5
S.S. transplants	3.0	3.2	2.7	2.6	13.8	10.4
With:						
Compost	2.9	3.2	2.5	2.4	14.1	9.2
Fertilizer	3.0	3.4	2.7	2.8	13.8	11.5

continued overleaf

Table 13 continued.

Continuous Manuring Experiments

	Un-manured	Compost	Fertilizer	Compost +Fertilizer
	Height in inches			
1+0 seedlings:				
Kennington (KT 104/5)	2.5	3.2	3.2	3.2
Wareham (W 104/5)	0.2	2.6	2.5	3.2
	Number of plants per sq. yd.			
Kennington (KT 104/5)	669	555	676	593
Wareham (W 104/5)	1,178	834	840	763
	Height in inches			
1+1 transplants:				
Kennington (KT 106/7)				
Compost raised seedlings	12.0	13.8	14.2	15.0
Fertilizer raised seedlings	12.2	14.0	14.4	14.9
Wareham (W 106/7)				
Compost raised seedlings	4.2	8.8	12.9	14.3
Fertilizer raised seedlings	3.6	8.8	11.3	13.3

At Kennington the first seedling crop after lupins was poor, but all other differences from previous cropping were small. At Wareham the seedlings following Sitka spruce seedbeds and transplants, i.e. continuous conifer cropping, were better than those after any of the green crops or fallow, but the Wareham transplants were best after rye and ryegrass.

For seedlings the differences between compost and fertilizer were small at both centres, though the fertilizer seedlings tended to be a little larger. Both in the rotation and in the manuring experiment at Wareham the transplants on fertilizer treated plots were considerably larger than on compost plots. The compost treated transplants had the pale appearance of plants suffering from nitrogen deficiency.

Both at Kennington and Wareham plant numbers were lower on compost seedbeds than on fertilizer seedbeds; a result that has often been obtained before at other centres and in other seasons.

Formalin and Fumigants on Sitka Spruce Seedbeds

Experiments were again carried out to compare formalin and chlorpicrin and to determine the best time and amount for the application of both materials (Table 14, Series A). In a large number of comparisons chlorpicrin equalled formalin. Where rates were tested they were chosen so as to straddle the amounts normally used in our experiments, i.e. 167 ml. and 333 ml. per sq. yd. of formalin, and either 12 or 24 shots of 2 ml. per sq. yd. of chlorpicrin. Our standard rates are 250 ml. of formalin and 16 shots of 2 ml. of chlorpicrin. Neither for formalin nor for chlorpicrin was there any improvement of the double rate over the single, and further tests with still lower rates of application are being carried out in 1954. For chlorpicrin both the dosage and the spacing is being varied. The intention had been to compare a December application with one made in February; but owing to the very wet, late autumn and early winter it was not possible to apply the first treatment until mid-January. The second was made at the end of February. There was therefore only a six weeks' interval between the so-called winter and spring applications. Differences between the two applications were generally small, but in the few cases where results differed (Old Kennington and Ringwood for formalin, and Bagley and Wareham for chlorpicrin) the earlier application had the advantage.

EXPERIMENTS TESTING FORMALIN AND FUMIGANTS, SITKA SPRUCE ONE-YEAR SEEDLINGS, 1953

Table 14

	Mean heights in inches			Number of Eelworms per plant
	Kennington K 68	Ampthill Am 30	Ringwood R 59	Ringwood R 59
Series A				
Untreated	1.8	1.8	1.4	100
Chlorpicrin—January	2.5	2.9	2.7	2
Chlorpicrin—February	2.5	2.9	2.8	4
Formalin —January	3.1	2.7	2.8	17
Formalin —February	2.5	2.7	2.0	89
	K 69	Am 31	R 58	R 58
Series B (Jan. treatments)				
Untreated	1.7	1.8	1.3	156
Paraformaldehyde	2.1	1.9	1.5	111
DD	2.1	2.7	2.8	4
Ethylene dibromide	2.2	2.5	2.8	2
Formalin	3.1	2.7	2.9	8

It appears from the results of this season, and from earlier ones, that it might be better to apply these treatments a considerable time before sowing. In the early winter bad weather may often prevent soil treatment, and it was therefore decided to explore the possibilities of applying formalin and several fumigation treatments during a summer fallow. Two series of experiments were laid out in the summer of 1953, testing the application of formalin and chlorpicrin in June, October, December and February, and of formalin, paraformaldehyde, ethylene dibromide and DD in June and December. These were sown in 1954.

In 1953 formalin, paraformaldehyde, ethylene dibromide and DD, were compared in a series of preliminary experiments in which all treatments were applied in January (Series B). At Ampthill and Ringwood, DD, ethylene dibromide and formalin gave closely similar increases in height, whereas at Old Kennington the response to formalin was considerably larger than that to the other two materials. Paraformaldehyde was as good as DD and ethylene dibromide at Old Kennington, but failed to increase plant height at Ampthill and Ringwood.

Dr. J. B. Goodey of the Nematology Department at Rothamsted continued his work on eelworms occurring on the roots of Sitka spruce seedlings and transplants. The last column of Table 14 shows that the number of eelworms (*Hoplolaimus uniformis*) is greatly reduced in Series A by chlorpicrin applied either in January or February, or by formalin applied in January, and in Series B by DD, ethylene dibromide and formalin. Formalin applied in February (Series A) and paraformaldehyde (Series B) show only a very slight reduction. Thus, there appears to be a close correlation between number of eelworm and seedling height in these two Ringwood experiments. At the other nurseries only negligible numbers of eelworms have been found. This suggests that only part of the benefit from fumigants is through control of eelworms.

Risks arising from the use of Chlorpicrin.

The following quotation is taken from *Plant Diseases, the Yearbook of Agriculture*, 1953. (U.S. Dept. of Agriculture, Washington.)

"Under certain weather conditions, a blanket of gas (chlorpicrin) may collect over a fumigated bed near the ground, then drift slowly over a nearby area, and cause severe injury to the plants growing there, especially at night when foliage is wet with dew. That does not always happen, but it is a risk that should be remembered when one fumigates seedbeds near growing crops".

In a set of experiments at four centres where it was necessary to inject chlorpicrin close to a standing crop of Sitka seedlings some of the seedlings turned brown and then died. At three centres the injections were done during a fog and at the fourth during rain.

In a transplant experiment at Ringwood many of the transplants died on plots which had been treated with chlorpicrin twelve weeks before lining out, but in parallel experiments at two other centres there were no harmful effects and response to chlorpicrin was good. More work may have to be done to determine the conditions under which damage above ground or through the soil may occur.

Formalin and Chlorpicrin on six Conifer species

At the four centres, Ampthill, Old Kennington, Ringwood and Kennington Extension, formalin and chlorpicrin, and a combination of the two, were tested on six conifer species sown in drills (Table 15).

EXPERIMENTS TESTING FORMALIN AND CHLORPICRIN, ONE-YEAR SEEDLINGS OF SIX SPECIES SOWN IN DRILLS

Table 15 Height in inches 1953

	Jap. larch	Doug. fir	Sitka spruce	Tsuga het.	Pinus contorta	Cors. pine
Ampthill (*Am* 33*A*)						
Untreated	5.3	4.3	1.7	1.5	2.0	1.8
Formalin	8.4	5.8	3.4	1.8	3.0	2.0
Chlorpicrin	7.7	5.9	2.7	1.7	3.0	2.1
Both	9.3	6.5	3.6	2.0	3.7	2.4
Old Kennington (*K* 63*A*)						
Untreated	6.5	5.5	1.6	1.1	1.6	1.8
Formalin	10.3	7.3	3.3	2.0	3.2	2.4
Chlorpicrin	10.3	8.0	3.2	2.2	3.5	2.5
Both	10.9	7.8	3.9	2.2	4.2	2.6
Ringwood (*R* 60*A*)						
Untreated	3.8	3.5	1.4	1.3	2.0	0.9
Formalin	5.4	4.8	2.4	2.3	3.2	1.7
Chlorpicrin	5.6	4.8	2.5	2.3	3.4	1.5
Both	5.2	4.0	2.6	2.6	3.1	1.4
Kennington Extension (*KE* 76*A*)						
Untreated	7.0	5.5	2.1	1.7	2.5	1.8
Formalin	9.2	6.0	3.0	2.2	4.0	2.2
Chlorpicrin	10.0	6.8	3.2	2.3	4.1	2.5
Both	9.8	6.4	3.5	2.2	4.4	2.2

At all centres and for all species the increases from formalin and chlorpicrin were considerable, but the differences in the effectiveness of the two materials were only small. At Old Kennington, Ringwood and Kennington Extension, formalin and chlorpicrin together were no better than either of the materials used alone, whereas at Ampthill there was a slight gain. In no case were the effects of formalin and chlorpicrin additive.

Forest Planting Experiments

In the following paragraphs some of the more prominent effects are discussed that have emerged from experiments involving the extension, or planting out in the forest, of trees raised under various nursery treatments, as well as from forest manuring experiments assessed at the end of the 1953 season.

Forest Experiments Planted in 1948

The *Ann. Rep. For. Res.*, 1950 (page 102; para. 14) describes in some detail the design of an experiment testing at four forests first-year seedlings and one-plus-one transplants raised either with compost in the Old Nursery at Wareham or with fertilizer in the New Nursery. Each forest plot was split to compare "no forest manuring" with an NP fertilizer applied shortly after planting. Six years after planting there is practically no difference between plants of similar age but different nursery origin, except at Broxa (Allerston Forest) where Sitka transplants from the Old Nursery are 8 inches taller than those from the New Nursery, and Scots Pine seedlings from the New Nursery are 8 inches taller than those from the Old. (See Table 16.)

HEIGHTS AFTER SIX SEASONS IN FOREST OF WAREHAM SEEDLINGS AND TRANSPLANTS RAISED WITH COMPOST IN THE OLD NURSERY AND FERTILIZER IN THE NEW NURSERY

Table 16 Height in inches 1953

	Height in inches 1948	Averaging forest manuring				Effect of NP fertilizer applied at Planting 1948			
		Decoy, Wareham	Dartmoor	Broxa, Allerston	St. Gwynno	Decoy, Wareham	Dartmoor	Broxa, Allerston	St. Gwynno
Sitka Spruce									
1+1 ex Old	7.2	22	38	59	73	15	17	16	2
1+1 ex New	5.9	18	38	51	72	13	19	18	1
1+0 ex Old	2.4	15	26	54	60	17	13	9	4
1+0 ex New	1.8	20	30	53	64	22	18	12	0
Scots Pine					King's				King's
1+1 ex Old	2.8	46	50	53	44	19	—3	10	—5
1+1 ex New	4.1	45	50	54	44	21	3	10	—4
1+0 ex Old	2.2	35	39	43	45	24	—2	11	—2
1+0 ex New	2.3	36	38	51	45	27	—2	4	3

After an initial response to forest manuring, Sitka plants at Decoy Heath, Wareham, have gone into check, but Scots pine continues to grow vigorously. At Broxa Sitka seedlings have reached nearly the same height as transplants. Manured Sitka seedlings and transplants put on annual shoot growth of 8-10 inches during the last two years and are now between 50-60 inches high.

At St. Gwynno, transplants with a recent average shoot growth of 12 to 14 inches now measure over 70 inches, and seedlings with a similar shoot growth over 60 inches. Growth of Sitka at Dartmoor, where planting had been done on old furrows on a very grassy site, continues to be slow, with an annual shoot growth of 5 inches. There were large responses to forest manuring on Sitka spruce at Decoy Heath, Dartmoor and Broxa, but none at St. Gwynno. On Scots pine manuring increased growth only at Decoy Heath and Broxa.

In forest manuring experiments testing nitrogen, phosphorus and potassium there is a slight benefit from nitrogen at only one centre, namely Broxa. On the grassy sites of Dartmoor, St. Gwynno and King's Forest nitrogen has encouraged the vegetation, apparently at the expense of the conifers. Phosphate has given considerable height increases at Broxa and Dartmoor ranging from 8 to 15 inches. There was a large response to potash at King's Forest. The differences of height in inches as shown by the 1953 assessments of Scots pine are:

	No potassium	*With potassium*
One-plus-one transplants	52	59
First year seedlings	32	46

Some trees on the "no potash" plots showed a yellow discoloration which was almost completely absent from plants that had received potash. Three years after planting, a topdressed application of a potassic superphosphate with a high potash content (10% P_2O_5, 20% K_2O) was tested on 1948 experiments at King's Forest, which had not until then received any potash manuring. A clear response to potash was shown by the assessments made at the end of the second growing season after application. (It is unlikely that the plants derived any benefit from the small amount of phosphate present in the potassic superphosphate, as phosphate had given no increased growth in other experiments on the site.)

It has often been suggested that heavy manuring in nurseries may yield plants which are "soft" and more liable to suffer frost damage when planted on exposed sites. In a number of extension experiments first year seedlings and one-plus-one transplants which had received average compost or fertilizer dressings were compared with plants which had been given additional dressings of nitrogen, phosphorus and potassium fertilizers in the nursery. The differences in height were small and irregular, and in this set of experiments there has been no indication that heavy dressings of nutrients had had any influence on subsequent growth.

Forest Experiments Planted 1950

Extension experiments of seedlings at Cwm Ysgawen, Coed Sarnau Forest, and Ridding's Wood, Kerry Forest, continue to show considerable benefit from steam at Ampthill, and from both steam and formalin applied to nursery seedbeds at Ampthill and Ringwood in 1949.

Table 17 shows the heights, after four seasons in the forest, of Sitka spruce seedlings and transplants raised with fertilizer or compost at three nurseries. Both at Cwm Ysgawen and Ridding's Wood the differences between the compost and fertilizer raised plants are very small.

HEIGHT OF SITKA SPRUCE RAISED WITH DIFFERENT NURSERY TREATMENTS, AFTER FOUR SEASONS IN FORESTS

Table 17

	Height in inches in nurseries 1949		Height in inches in forests 1953			
			Cwm Ysgawen		Ridding's Wood	
	Plants raised with:		Plants raised with:			
	Compost	Fertilizer	Compost	Fertilizer	Compost	Fertilizer
Planted 1950 *as:*						
1+0 *seedlings*						
Wareham	1.9	1.8	26	25	31	28
Bagley	1.6	1.2	14	15	18	19
Kennington Ext.	1.5	1.4	13	13	22	23
1+1 *transplants*						
Wareham	6.2	7.4	32	36	39	41
Bagley	8.6	7.6	38	35	38	35
Kennington Ext.	5.3	5.3	22	22	30	31

In forest manuring experiments testing N, P and K, superphosphate increased growth of Sitka spruce at Cwm Ysgawen.

Forest Experiments Planted 1952

In 1952, extension and manuring experiments on Sitka spruce seedlings and transplants were carried out at two centres. One site is at 1,220 feet in Cwmogwr Forest, Glamorgan, a uniform *Molinia* site with a fair thickness of peat over Pennant Grit. The other site is at Pincyn Llys, Clocaenog Forest at 1,250 feet on Denbigh Grit. It carried dense *Calluna* until it was burnt off shortly before ploughing in 1951 and at the time of planting the vegetation was almost pure *Vaccinium*. Both sites were hit by blizzards very shortly after planting which caused severe damage to experimental plantings, particularly at Cwmogwr. At Cwmogwr most of the plants had lost their needles. At Pincyn Llys most plants had turned brown and on this site, too, many had been stripped of their needles.

HEIGHT AND PERCENTAGE DEATHS OF SITKA SPRUCE RAISED WITH VARIOUS NURSERY TREATMENTS AFTER TWO SEASONS IN FOREST

Test on seedlings raised with compost or fertilizer; and on transplants raised with compost or fertilizer in the seedbed, and compost or fertilizer in the transplant lines.

Table 18

	Height in inches				Percentage deaths 1953			
	1951 *Nurseries*		1953 *Pincyn Llys*		*Pincyn Llys*		*Cwmogwr*	
	Seedlings raised with		Seedlings raised with		Seedlings raised with			
	compost	fert.	compost	fert.	compost	fert.	compost	fert.
Experiment 1 *Planted* 1952 *as:* 1+0 *Seedlings*								
Wareham	3.3	3.4	8.4	6.8	8	21	68	66
Bagley	3.2	3.5	7.6	7.0	8	18	50	61
Kennington Ext.	3.9	4.0	7.0	6.8	9	8	40	36
Ringwood	3.4	3.2	10.0	6.1	7	16	39	52
Old Kennington	2.3	2.6	6.3	4.8	9	9	35	44
Experiment 2 *Planted* 1952 *as:* 1+0 *Seedlings*								
Wareham	2.4	2.7	6.9	6.9	12	16	54	60
Kennington Ext.	2.6	3.2	5.7	5.7	16	16	73	64
1+1 *Transplants*								
Wareham								
Compost	5.7	5.4	13.5	12.3	1	2	34	27
Fertilizer	5.9	6.0	13.4	13.1	0	0	14	21
Kennington Ext.								
Compost	9.2	8.6	14.8	13.7	0	0	10	12
Fertilizer	9.8	9.4	15.4	13.6	0	1	8	9

Table 18 gives the heights at Pincyn Llys only, and the percentage deaths at Pincyn Llys and Cwmogwr, of seedlings and transplants raised with compost or fertilizer at several nurseries. At Cwmogwr the losses were so great that no heights are given. The experiments have been abandoned. In experiments at Pincyn Llys higher losses have occurred amongst fertilizer-raised than amongst compost-raised seedlings, and growth has also been less on seedlings grown with fertilizer. Plant analysis has shown that until the rate of potash manuring in nurseries was increased in 1952 compost plants had considerably higher potash contents than fertilizer grown plants. Under the extreme conditions of the 1952 spring this difference in potash content may have affected survival and growth. In Experiment 2 the results from compost and fertilizer raised plants were very close both for growth and survival.

In Experiment 1 all seedlings from Ringwood and Old Kennington, and half the seedlings from Wareham, Bagley and Kennington Extension had been grown on formalin-treated plots. There were no differences between seedlings raised with and without formalin.

SOIL MYCOLOGY

By Dr. IDA LEVISOHN,

Bedford College for Women, London University

Rhizosphere effect of mycorrhizal mycelia

In the *Report on Forest Research* for 1952, experiments were described showing the rhizosphere effect produced by mycorrhizal fungi on tree seedlings. Further experiments carried out in pot-cultures have demonstrated the rhizosphere activity of both ectotrophic and endotrophic mycelia.

Effect on birch.

It has been shown that good birch seedlings grown under very favourable conditions received an additional stimulus from the rhizosphere activity of *Boletus scaber*, a well-known mycorrhizal associate of birch.

The experiments under consideration refer to pot-cultures of *Betula verrucosa* grown in composted Wareham soil. They were divided into two series, one inoculated with mycelium of *Boletus scaber* from pure culture, the other kept as uninoculated controls. No mycorrhizal infection took place during the first year of growth (confirming the observation that, in many tree species, composting of soil delays mycorrhiza formation). From the later part of the first growing season onward, the seedlings inoculated with *B. scaber* started to exhibit increase in shoot length, improvement in colour of foliage, and enlargement of leaf area. By way of example may be cited the figures for measurements of leaf areas of three plants inoculated and three plants not inoculated. (See Table 19.)

LEAF AREAS IN SQUARE CENTIMETRES OF BIRCH SEEDLINGS INOCULATED WITH *Boletus scaber* AND CONTROL SEEDLINGS NOT INOCULATED

Table 19

	Inoculated			Not inoculated		
	A+	B+	C+	A	B	C
Areas of individual leaves in descending sequence	51.0 46.9 35.4 32.1 21.4 25.7 25.7 27.1 23.3 29.0	48.2 37.2 22.1 20.0 20.0 22.2 25.6 27.0	39.0 38.8 35.0 21.6 16.1 17.7 14.8	18.8 22.8 24.8 22.6	15.8 16.9 18.0 17.2 17.3	10.1 11.0 14.2 18.1
Average	31.76	27.75	26.18	22.25	21.3	13.35

Note: Measurements were made with a planimeter of the areas of the leaves still remaining on the current year's axis, on September 16th, 1953. The leaf at the extreme apex was not recorded since growth for the season had ceased before it had had time to reach its full size; with this exception, the figures represent the areas of the leaves from apex downwards in each plant.

Note growing tendency towards enlargement of the leaves of A+, B+, C+, at the close of the season, whereas the tendency shown by plants A, B, C, is rather the reverse.

Effect on Thuja plicata

Sand-cultures of *Thuja plicata* which were inoculated with a mycelium isolated from mycorrhizas of Lawson cypress showed improvement over those not inoculated. Measurements of shoot extension taken during the first season of growth supplied the following figures:—

Average shoot extension of inoculated series (104 plants)—23.4 mm
„ „ „ of control series (96 „)—14.1 mm

Effect of Mulching on Mycorrhizal Root Infection

Evidence of the striking effect of mulching on the fungal root associations of a number of forest trees was presented in the *Report on Forest Research* for 1951. Since then, more instances of radical changes in the mycorrhizal equipment brought about by mulching have been recorded.

A remarkable condition of root infection was observed to be present in root systems of Lawson cypress (Expt. War. 29 P.37) which had been under heather mulch. Whilst a large portion of the dense mat of roots developing in the mulch showed endotrophic infection of the kind characteristic of Lawson cypress, other root branches carried conspicuous nodular bodies which, on microscopic examination, turned out to be tuber mycorrhizas of typical ectotrophic structure. The occurrence of both types of mycorrhizal infection in the same species (and in the same plant) is extremely rare; it has only been described for some juniper plants growing in Sweden, and it is the first time that a case of such "double infection" has been recorded in this country.

This phenomenon, which points to a certain mycorrhizal elasticity of the tree roots, is of interest in many respects. In order to analyse the conditions favouring the formation of ectotrophic associations in a species generally regarded to be endotrophic, isolation of the ectotrophic mycorrhiza-former and inoculation experiments are to be carried out.

Study of "Net" Formation Caused by Root Fungi of Forest Trees

A convenient method has been found for studying the formation of the net structure which, in nature, is commonly produced by the so-called pseudomycorrhizal mycelia in the inter-cellular spaces of the root cortex. There are indications that this method can be adapted for reproducing the internal Hartig net and the external mantle formed by true mycorrhizal fungi. In the initial stage, the experiments were concentrated on pseudomycorrhizal mycelia since this group of fungi is not difficult to grow and the species are readily recognizable by the dark colour of their hyphae.

The new method, in addition to supplying useful information concerning the conditions for net formation, provides an easy test for identifying fungi of the pseudomycorrhizal type, i.e. forms of *Rhizoctonia* and *Mycelium radicis atrovirens*, as different from the "trivial" soil mycelia like *Stemphyllium*, *Alternaria*, *Pullularia*, etc. The former group of fungi are the most common causes of pseudomycorrhizal infections in this country; the latter, so far, have not been observed to infect the roots of forest trees.

In the experimental sets, the natural root tissues were replaced by certain cellulosic fibres which proved to be an ideal substitute. They were better suited for studying net formation than the root tissues whose intercellular spaces were too small for the detailed observations intended to be carried out. Pure cotton cellulose, filterpaper, cottonwool and similar fibres were the main materials employed in the experiments.

It was demonstrated that, under certain conditions, largely dependent on the constitution of the nutrient medium supplied in the synthetic culture, and the width of the central canal of the fibres exposed to infection, a net structure was formed within the lumen by all pseudomycorrhizal fungi tested. The factors found to be responsible for inducing net structure under the experimental conditions, conform with those suspected to determine net formation by the pseudomycorrhizal fungi in the living root tissues under natural conditions.

None of the "trivial" soil mycelia used in these experiments were observed to form a net within the cellulose fibres. Neither did the conditions, so successful in the case of the pseudomycorrhizal fungi, promote net formation of the true mycorrhizal mycelia tested.

There are now experiments in progress designed to bring about net and mantle structure of mycorrhizal fungi by using special "artificial" materials. *Mycelium radicis nigrostrigosum*, the jet-black mycorrhiza-former, and *Boletus scaber*, both very fast growing and not exacting as regards nutrient requirement, serve as test mycelia.

FUNGAL DAMAGE TO ROOTS OF SITKA SPRUCE SEEDLINGS IN FOREST NURSERIES

By D. M. GRIFFIN

Botany School, University of Cambridge

IN many experiments carried out by the Forestry Commission of recent years, partial sterilization of the soil by means of steam, formalin and various fumigants has produced outstanding improvements in the vigour of coniferous seedlings, and especially of Sitka spruce, grown therein. Mycological examinations of seedlings raised in various old nursery soils were made by Dr. J. H. Warcup several years ago, and he also tested the pathogenicity of various fungi isolated from diseased roots. This work, which ceased temporarily when Dr. Warcup left the country, has now been re-started. One of its aims is the devising of a suitable system of root disease rating, together with a method for identifying the particular fungal pathogen concerned. Such techniques would greatly increase the value of the information to be obtained from the experiments now being conducted for the Forest Nursery Nutrition Sub-Committee, on different methods for partial sterilization of old and "sick" forest nursery soils.

For the first phase of this work, a thorough visual and mycological examination of roots of Sitka spruce seedlings growing in various old and "sick" forest nursery soils has been planned. During the winter of 1953/54, soils collected from Wareham, Ringwood, Kennington Old and Kennington "Three" nurseries were placed in glasshouse containers, and Sitka spruce seed sown therein, steamed soil being used for the control containers. Heavy damping-off occurred in Kennington Old soil, less in those from Ringwood and Kennington Three, and none in the Wareham soil. Samples of seedlings from each soil, and from the steamed control soils, were taken at intervals, and root disease ratings were made. Selected and well-washed root portions were plated-out on agar, after appropriate treatment and with suitable precautions, for isolation of possible fungal pathogens. Potentially pathogenic species of *Pythium* were isolated regularly from killed root tips of seedlings growing in the two Kennington soils and in the Ringwood soil. These results confirm the tentative conclusion reached by Dr. Warcup, that *Pythium* spp. are the chief fungal pathogens in these old forest nursery soils, and that they typically cause killing of root tips. No other fungi likely to be pathogenic were isolated from the seedling roots, with the possible exception of *Fusarium oxysporum*, which is being tested along with the *Pythium* species in inoculation experiments.

No pathogenic fungi were isolated from the roots of seedlings grown in Wareham soil, in which no obvious damping-off or root damage occurred. The rarity of seedling disease on Wareham soil agrees with experience at other nurseries on acid heathland sites, and an actual inoculation experiment carried out with *Pythium ultimum* has shown that this type of soil is relatively unfavourable to development of *Pythium* damping-off.

During the 1954 season, observation plots of Sitka spruce seedlings were established for the making of mycological observations at Ampthill, Wareham, Ringwood, Bagley Wood and Kennington Nurseries.

EFFECTS OF TREE GROWTH ON SOIL PROFILE DEVELOPMENT

By Dr. T. W. WRIGHT,

The Macaulay Institute, Aberdeen

Moisture Studies

A joint paper on the neutron scattering method of soil moisture measurement has been written in collaboration with the Section for Radioactive Studies of the Macaulay Institute, and accepted for presentation at the Second Radioisotope Conference (Oxford, July 1954). The method appears to have several advantages over existing techniques; the unit is independent of the tension at which moisture is held in the soil, and it is only very slightly affected by soil organic matter. Provided, therefore, that it is calibrated on a volume basis, to allow for variations in soil density, a single laboratory calibration enables it to be used on a wide range of soil types. It measures the average moisture content of a definite and relatively large volume of soil, thus minimising errors due to natural moisture variations in non-homogeneous soils. The accuracy and reproducibility of the method compare favourably with that obtainable by established techniques. The development of a fully portable apparatus suitable for field use now depends chiefly on the design of a suitable meter for measuring the neutron flux.

A comparison has been made between the response of the fiberglas-gypsum moisture block (Youker and Dreibelbis, *Trans. Amer. Geophys. Un.*, 32, 447, 1951) and the plain gypsum block used in the Culbin moisture studies (*Rept. For. Res.*, 1953) which confirms that the former has a better response in the moisture range: field capacity-saturation, which is often of importance under British conditions. The electrical resistance method employing this type of block is most effective in indicating the nature of soil moisture trends, but owing to the difficulty of accurate calibration and to possible hysteresis effects between the drying and wetting cycle, its value for quantitative measurements is limited.

Corsican Pine Nutrition

The work at Culbin Forest (summarised last year) has shown that soil moisture content in sand dune plantations improves after thinning, and that the phosphate content of the Culbin sand is particularly low. In order to investigate whether the improved moisture conditions result in a measurable improvement in nutrient uptake by trees, chemical analyses are being carried out at monthly intervals on leaf samples collected from two sets of plots of Corsican pine thinned to different grades, one showing satisfactory growth and the other showing poor growth with marked chlorosis.

These are being compared with similar samples from Corsican pine growing on a more normal soil at Monaughty Forest, some ten miles from Culbin. Preliminary results suggest that heavy thinning improves phosphate uptake, and possibly also affects the uptake of other major nutrients. The experiment is being continued for a full year, to enable seasonal changes to be studied also.

The low phosphate content of the sand suggests that phosphate manuring might be beneficial, particularly in the early stages of establishment before the enrichment of the surface soil by the leaf fall becomes effective. A small phosphate manuring experiment, using ground mineral phosphate broadcast at the rate of 2 oz. per sq. yd., has therefore been laid out in five-year-old Corsican pine growing on the dunes; results will be measured by periodic leaf analyses and observations of height growth over several growing seasons.

The thesis "Profile Development in Sandy Soils under the Influence of Heath and Forest" has been accepted for the degree of Doctor of Philosophy by the University of Aberdeen. A preliminary survey is being carried out in order to find sites suitable for extending the work on profile development to a range of more mature soil types.

STUDIES OF FACTORS AFFECTING TREE GROWTH ON CALLUNA HEATHLANDS

By Dr. L. LEYTON,
Department of Forestry, Oxford University

The Influence of Artificial Shading of the Ground Vegetation on the Nutrition and Growth of Sitka spruce in a Heathland Plantation

In July 1952, in an area of checked Sitka spruce growing on Hackness (Broxa) Moor, Allerston Forest, Yorkshire, the heather surrounding the trees was shaded by means of a framework of wooden laths. By the following year this had resulted in significant increases in the dry weight, nitrogen and manganese contents of the needles, accompanied by a marked stimulation to height growth compared with trees on the untreated heath. Parallel experiments on plots from which the heather vegetation had been previously removed, revealed little response to shading. The results confirm the importance of early suppression of the ground vegetation in raising spruce plantations on heathlands and offer an explanation for the commonly observed response of this species grown on such sites with a pine or larch nurse when the latter forms a closed canopy.

The Influence of Certain Environmental Factors on the Metabolism and Growth of Tree Roots

Oxygen Tension. Studies on excised root tips of Corsican pine, Scots pine, Japanese larch and Sitka spruce (sampled from adult trees in the field) reveal a marked influence of the oxygen tension of the medium on the rate of respiration. No great differences have been found between the four species investigated in their response to different degrees of aeration, though at very low oxygen concentrations, Corsican pine tends to show the greatest tolerance and Scots pine the least.

Investigations are continuing into the significance of these responses with particular reference to soil aeration and root growth.

Litter and Humus. Cold water extracts of Scots and Corsican pine litter and raw humus have been found to exert a marked stimulation on the rate of respiration of excised root tips of these species. Preliminary observations suggest that extracts of the H. layer (lowest humified zone) are more powerful in this respect than extracts of the L. (surface litter) & F. (intermediate decomposition) layers of the humus. This would appear to be a significant factor in the localisation of tree roots to this horizon, and further experiments are being carried out to investigate the phenomenon in more detail.

VARIATION IN THE NATIVE SCOTS PINE OF SCOTLAND

By A. CARLISLE
Department of Forestry, Aberdeen University

The work on the morphological and silvicultural variations of the native Scots pine of Scotland was completed and presented in the form of a thesis. It was found that the native Scots pine constitutes a heterogeneous geographical variety (var. *scotica*, Schott), and exhibits a characteristic range of morphological variants. The incidence of these variants is similar to those of the Scots pine of Southern Sweden (var. *septentrionalis*, Schott).

The principal habit variants in Scotland are var. *horizontalis* Don and *forma ascensa* (Carlisle). *Forma condensata* Fries, *forma fastigiata* Carrière, *forma pyramidalis* (Elwes & Henry), and *forma pendula*, Caspary, are all less common.

The bark variants appear to be influenced by the age of the trees, but may in some cases be genetically controlled. The leaves exhibit variations in their colour, twist, persistence, resin-canal number and position, and stelar sclerenchyma development, which appear to be independent of environmental and developmental factors. The female cones exhibit considerable variation in form and apophysis development, and include *forma plana* Christ, *forma gibba* Christ, and *forma reflexa* Heer. The abnormal *forma conis aggregatis* Syreitschikow is present but rare. A great many seed and seed-wing colour variants occur, together with striped and unstriped seed-wings.

The male inflorescence varies in form (cylindric to ovate) and colour (yellow, pink-yellow, violet-purple red).

The poor growth of the trees in the native woodlands was found to be due to adverse environmental conditions and lack of systematic treatment. On more favourable sites, the native Scots pine attains considerable size and is of great silvicultural value.

These results will be incorporated in a general work on native Scottish Scots pine woods now being prepared. The ecological survey of the native pine woods begun in 1950 was continued and, apart from scattered minor woodlands, completed.

MORPHOLOGICAL VARIATIONS IN TREE SPECIES

By Dr. E. V. LAING,

Department of Forestry, Aberdeen University

FURTHER investigations into the possible determination of the percentage of hybrid seed in a sample collected from Japanese larch cones has been carried out. Besides morphological features which distinguish Japanese and European larch seed leaves, colour tests have been tentatively tried with so far only moderate success. Methanol is one chemical which gives some degree of success.

In the method first devised, whereby the seed was germinated and the seed leaves sectioned, the results have been to some extent vitiated by the discovery that there does exist some variation in the European larch seedling. The variations seem to be related to seed origin. This variation is being further investigated by the examination of seedlings of different seed origins. Japanese larch seedlings so far have proved to be very constant in their structure.

The cotyledons of Japanese and European larch differ in the following characters:—

(1) Thickness of cuticle—thin in Japanese larch and thick in European.

(2) Papillate epidermis in Japanese larch and smooth epidermis in European.

(3) The number of cells in the endodermis of Japanese larch, when the cotyledon is seen in cross-section, is 12 to 15; whereas in European larch it is commonly 15 or more. But one race at least of European larch has been found to conform to the Japanese larch in this feature.

(4) No sclerenchyma cells in the bundle of Japanese larch, varying number of sclerenchyma cells in European larch.

(5) More definitely armed mesophyll cells in European than in Japanese larch. In seedlings from Japanese larch mother trees, one or more European larch characters may be present and such seedlings are taken to be hybrid.

Large numbers of seedlings of Japanese, European and hybrid larches have been examined for number of cotyledons and length of cotyledons, but no significant differences have been found.

Pinus contorta and Pseudotsuga taxifolia

Further work has been done on the botanical differences of *Pinus contorta* and *P. murrayana*.

In the Douglas fir, *Pseudotsuga taxifolia*, the occurrence of stone cells in the mesophyll of the leaf seems to be a reliable character for the definition of intermediate forms.

INVESTIGATIONS OF THE BIOLOGY OF CRYPTOSTROMA CORTICALE AND THE SOOTY BARK DISEASE OF SYCAMORE

By NOEL F. ROBERTSON,
Botany School, Cambridge

MR. J. A. Townrow, who was carrying out this work, left Cambridge in the summer of 1953 and observations on his experimental material have been continued by Miss Helen Purnell of the Forests Commission of Victoria, Australia, and by the writer.

The biology of *Cryptostroma corticale* in culture was briefly described by Mr. Townrow, last year. The main objects of the investigation, namely the development of a method of artificial inoculation, the demonstration of the pathogenicity of the fungus, and the effect of environmental factors on the disease, have not yet been fully achieved. But the experiment reported below has had a measure of success. The trees for this experiment were received as one-plus-one transplants from the Forestry Commission nurseries in the spring of 1952. They were lined out at the Botany School Field Station, Cambridge, and allowed to grow until the autumn of 1952 before the first inoculations were done. Inoculations were made on the cut end of the main shoot at bi-monthly intervals and the following methods of inoculation were used.

1. A suspension of spores of *Cryptostroma corticale*, in sterile distilled water, was applied to the cut end of the shoot. The inoculated surface was then covered with damp cotton wool and tinfoil.

2. The cut shoot was dusted with dry spores of *C. corticale*. The end of the shoot was then enclosed in a four by one inch specimen tube and the opening sealed with dry cotton wool.

3. A suspension of spores of *C. corticale* was applied to the cut end of the shoot and the end of the shoot was enclosed in a specimen tube as in 2.

4. Controls were treated in an exactly similar fashion to 1, 2 and 3, but without spores of *C. corticale*.

Three trees were inoculated by method 1 and four trees were inoculated by methods 2 and 3 at each date. Two trees were used as controls for each of the methods of inoculation at each date.

The number of affected trees for each method of inoculation, recorded in May 1954, is shown in Table 20 below.

THE NUMBER OF SYCAMORE TREES INFECTED BY CRYPTOSTROMA CORTICALE FOLLOWING INOCULATION BY THREE DIFFERENT METHODS AT SIX DIFFERENT TIMES OF YEAR

Table 20 No. of trees showing infection by Cryptostroma corticale

Date of inoculation	Method No. 1 (3 trees)	Control No. 1 (2 trees)	Method No. 2 (4 trees)	Control No. 2 (2 trees)	Method No. 3 (4 trees)	Control No. 3 (2 trees)
3rd October, 1952	0	2	4	1	3	1
3rd December, 1952	0	0	2	0	4	1
3rd February, 1953....	0	0	3	0	3	2
3rd April, 1953	3	2	3	2	4	0
3rd June, 1953	2	0	3	0	3	1
3rd August, 1953	2	1	3	0	4	1
Total	7	5	18	3	21	6

The table shows that infection of cut stumps can take place at all times of the year but that Methods 2 and 3 are superior to Method 1 in the inoculation of young trees. The table gives a false impression of the pathogenicity of the organism, for in the majority of cases the cut end has died back to the first node, to form a snag on which the lesions of *C. corticale* have formed. Similar snags are to be found on the uninfected controls. In a number of the inoculated trees the snag has fallen off and no external evidence of the continuance of fungal infection remains. However isolations made in October 1953 from two trees inoculated in April 1953, showed that *C. corticale* was present for about one inch below the node to which the snag died back, in living wood. No stain was associated with the presence of the fungus. In some 17 trees no true snags had formed by May 1953 on some lesions of *C. corticale* could be found on the cut stem. The area involved was the bark of the terminal six inches of cut stem, and this diseased and dead portion passed imperceptibly into the living wood below. The records show that all but two of these trees were inoculated on the new wood in August 1953. There seems to be a possibility that the fungus will have the opportunity of extending into the living part of the tree—in these inoculations. if it is capable of doing so.

RELATIONSHIPS BETWEEN LARCH CANKER AND TRICHOSCYPHELLA WILLKOMMII

By Dr. J. G. MANNERS,
Department of Botany, Southampton University

WORK has continued along two main lines, the study of the effects of the artificial inoculation of larch with *Trichoscyphella willkommii* in the absence of frost, and the production of artificial and controllable frost damage.

The inoculation experiments in a frost-free locality near Penzance (See *Ann. Reps. For. Res.* 1952 and 1953) have now been concluded. Of 52 trees inoculated with *T. willkommii*, 35 (67%) became infected; some cankers had persisted for three years and very few, once formed, healed over. Of 36 trees inoculated with *T. hahniana*, only three became infected, and all these cankers subsequently healed. In July 1953, all inoculated stems were removed for anatomical investigation. Results so far obtained show that the inoculation wound is healed within a year, but that where infection has occurred the cambium above the wound is again damaged the following year, and a canker results. The histological peculiarities of such cankers have much in common with both those of cankers occurring naturally and those of frost-damaged tissues.

In inoculation experiments with potted trees of European larch protected from frost, results so far obtained indicate that the trees of Munsterthal origin are more susceptible to *T. willkommii* than those of Polish origin, two Scottish provenances being intermediate. In similar experiments, Japanese larch proved markedly resistant: the only two trees infected had been inoculated with cultures from European larch. Other results have shown that cultures from Japanese larch can infect European larch, so it now seems clear that the fungus is not divided into separate physiologic races on the two host species.

An apparatus has been constructed which can direct a temperature-controlled cold air stream against the bark of a young larch. Frost-damaged areas have been produced thus, and their subsequent history in the presence and in the absence of *T. willkommii* will be followed.

Earlier results have now been published in *Trans. Brit. Mycol. Soc.* 36, 362-374, 1953.

BIOCLIMATIC STUDIES ON THE PINE LOOPER MOTH, BUPALUS PINIARIUS

By Dr. N. W. HUSSEY,
Department of Agricultural and Forest Zoology, University of Edinburgh

THIS study has been initiated to provide detailed information on the climatic tolerance of *Bupalus piniarius* with the long-term object of predicting the areas within which outbreaks can be expected.

Such an investigation necessitates a knowledge of the microclimates within which the insect develops, and so a temperature measuring instrument, incorporating thermistors and a sensitive galvanometer, has been designed and constructed. This apparatus, together with capillary evaporimeters, will be used to determine the range of temperature and evaporation to which larvae are exposed whilst feeding on the foliage. As it is well known that the larvae have a variable feeding period which may extend into mid-winter, and so expose the final and prepupal instars to various bacterial and fungal diseases, it is proposed to attempt to define those conditions which lead to slow larval development. A flow-apparatus has therefore been constructed in the laboratory so that air of fixed temperature and humidity can be passed over the needles to demonstrate the effect of the physical environment on larval feeding activity.

To provide the large numbers of larvae required for these and other studies, an insectary has been constructed over a Scots pine tree at the Bush Estate, Midlothian.

Preliminary investigations have also been made on the following:

(*a*) Fecundity at different temperatures.
(*b*) Effect of temperature and humidity on egg-hatching.
(*c*) Time interval between feeding and frass deposition by individual larvae.
(*d*) Light tropisms of the larvae of different instars and varying nutritional states.
(*e*) Behaviour of larvae in evaporation gradients.

SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY

Rothamsted Experimental Station, Harpenden

DURING the present year the writer has completed an account of his investigations of the arthropod fauna of a heathland habitat in the Allerston Forest area, North-east Yorkshire. One paper has appeared, and a further four are being prepared for publication. In these investigations the Acarina fauna—numerically the most important group—have been studied in greatest detail. Work has now commenced on an examination of the other animal groups, especially the Collembola. It is intended to identify the main species present, and ascertain the quantitative structure of the population. One paper is concerned with the process of extraction of soil fauna using a funnel method. Further investigations have been carried out to clarify some points arising out of the earlier studies of extraction technique.

Preliminary investigations have commenced to consider in greater detail the litter fauna of different tree species, singly and in mixture, together with their associated humus formations. It is intended to consider especially the food habits of individual species of Acarina and Collembola occurring in the litter. A problem encountered in the search for suitable sites for this work is the absence of information concerning the soil properties of what are otherwise suitable locations. However some plantations in Thetford Chase, Norfolk, appear promising, and Ovington's (1953) investigations provide valuable information of the chemical and physical attributes of the soils in this area. The writer has made a preliminary survey of the meiofauna of single species plots at Olleys Farm, Thetford Chase, one of the plantations sampled by Ovington.

With the intention of investigating the effect of environmental factors such as precipitation, a search has been made for other areas with thin iron-pan soils similar to that encountered in parts of the Allerston Forest. A site near Bolton, Lancashire, has been sampled to ascertain the effect of the much higher rainfall prevailing in this area. Preliminary results would suggest that more attention should be paid to the relative proportions of the various layers of the raw-humus horizon. The Bolton samples have a well-developed F layer, and this may partly account for the greater biomass and faunistically richer population inhabiting this site. The writer is greatly indebted to Mr. Edward Crompton and other members of the Soil Survey team at present working in Lancashire, for their generous assistance and advice.

Reference

Ovington, J. D. (1953). Studies of the development of woodland conditions under different trees: I. Soils pH. *Journ. Ecol.* 41: 1953 (13-34).

EFFECTS OF SHELTERBELTS ON THE MICROCLIMATE

By J. M. CABORN,

Department of Forestry, University of Edinburgh

THE object of this investigation is the collection of scientific evidence as to the best site, type and structure of shelterbelt which would afford the most efficient shelter, particularly in connexion with stock-rearing and forestry on upland areas.

The programme of microclimatic investigation is as follows:

(*a*) to determine the most suitable instruments for the investigation and to devise experimental methods with particular reference to study of wind and temperature conditions but also involving atmospheric humidity and evaporation.

(*b*) To study wind conditions on bare hillsides and in valleys in connexion with the siting of shelterbelts.

(*c*) To study microclimatic influences in the vicinity of various shelterbelts in order to determine the ideal shelterbelt in terms of width, vertical structure and composition by species.

The preliminary work of this programme has been completed. Wind studies are made almost exclusively with the "Sensitive Type IV" Cup-anemometer manufactured by Casella & Co. Ltd., London. Measurements are made at 1.5 metres (4 ft. 11 in.) above ground level. The field technique involves the use of a control station, and periodic measurements made at other points are related to the control station readings at the same time. Temperature studies are made with dry-bulb thermometers; atmospheric humidity is measured by means of the whirling hygrometer, and evaporation studies will involve the use of one of the standard types of atmometer available.

Investigations have already been made in the vicinity of several shelterbelts and will continue during summer and winter conditions. Preliminary studies have been made in a typical valley of the Pentland Hills, in Midlothian, in an area where no shelterbelts exist at the present time; these will be continued.

It is hoped that, during the winter, studies may also be possible of snow drifting near different types of shelterbelts.

PHYSICAL CHEMISTRY OF FOREST SOILS

By P. J. Rennie,
Imperial Forestry Institute, Oxford

Investigations on the effects of afforestation upon physico-chemical properties of moorland soils in North-East Yorkshire were continued. The very extensive statistical work required for the full interpretation of soil aeration and "available" water data from over 500 soil profiles and representing four years continuous measurements, is nearing completion.

Evidence from several localities has demonstrated a fundamentally important physical property of *Calluna*, *Erica-Scirpus* and *Eriophorum* raw humus, viz., the extremely small change in water content, equivalent to 0.5 inches of rainfall, representing the difference between an upper water content associated with the onset of poor aeration, and a lower water content associated with the onset of water deficiency.

This property, combined with the high water retentivity of the raw humus and the normal distribution of rain showers, has explained why a poorly aerated raw humus can persist for almost all the year on uncultivated moor soils of very varied mineral texture, although a water-impermeable mineral soil or horizon beneath the raw humus can reduce still further the aerations of the raw humus.

Certain properties are associated with this almost continually poor aeration, which was considered to be one of the principal factors causing the retardation of early tree growth, or its virtual failure, upon uncultivated moorland. Anything reducing the aeration further, such as heavier rainfall or basin topography, could intensify the retardation effect.

Deep ploughing was of immense value in being able to provide immediately a rooting zone i.e., the raw humus, well aerated in winter and summer, which zone in the case of plantations established without cultivation, may only be obtained after the formation of closed canopy.

But ploughing and quite prolonged afforestation, both with coniferous and deciduous species, had only the smallest effect upon total soil porosity or structure, so that the greatly improved aeration they caused, was always unavoidably accompanied by a drastic reduction in the "available" water level within the main tree rooting zone.

Mulching could offset this disadvantageous effect of ploughing by somewhat increasing the soil water content; increased amounts of "available" water were held, without the air content being simultaneously reduced to the deficiency level.

But the low contents of "available" water in the main tree rooting zone in summer, particularly under plantations of Japanese larch and Sitka spruce and older stands of Scots pine, pointed to the desirability of increasing the depth of the rooting zone, for climatic records showed a relatively high frequency of dry summer spells intensive enough to deplete all "available" water from the raw humus and upper mineral horizons.

Thus the poorly structured moor soils were adverse to tree growth primarily by their poor aeration in the uncultivated state and secondarily by their proneness to summer water deficiency in their afforested state.

These intrinsic soil adversities need not be accepted as inescapable phenomena restricting timber production, for former *Calluna* moor soils have been studied, where the earlier application of appropriate soil ameliorants has so deepened and increased the rooting zone that soil aeration and "available" water are both adequate, both in winter and in summer.

Extensive analytical work has been continued by Miss M. Lewis on materials from the twenty principal site types of the investigation.

The interpretation of the soil nutrient availability data is being completed, but the termination of the investigation will leave some unfortunate gaps.

Natural *Calluna* moorland soils, derived from a variety of geological formations, showed extreme acidity and low concentrations of available nutrients, particularly calcium and manganese.

Of all horizons in these soils, the raw humus represented the most valuable source of available nutrients, particularly for calcium, phosphorus and manganese; the underlying bleached horizons constitute unfavourable rooting zones by reason of their high soluble aluminium concentrations relative to calcium.

Studies on former *Calluna* moor now supporting mature plantations, and on soils supporting high quality class tree growth, suggested that the levels of available potassium and phosphorus in the natural *Calluna* moor, would not seriously limit tree growth for many years after afforestation. But the levels of available and total of reserve calcium in all horizons were outstandingly low, when the calcium demands of the timber crop were considered, suggesting that the known decline in mature coniferous growth rate might be prevented by the application of a calcium-containing material.

Prolonged growth of deciduous and coniferous species upon *Calluna* moorland brought about an increase of calcium concentration, which was marked within the litter horizon and slight within the upper raw humus horizon. This was accompanied in both cases by heavy litter production and increased depths of raw humus. The pH of the deciduous litter was never higher than 3.7, and the larger soil-mixing fauna were absent, hence prolonged deciduous growth gave rise to a soil-surface immobilisation of calcium quantitatively similar to that under the conifers.

On these soils, therefore, beech, birch and oak appeared unable, after sixty to seventy years growth, to bring about, by themselves, that measure of soil improvement which would justify their inclusion in, or replacement of, a coniferous plantation.

On the other hand, the present method of growing pure coniferous crops, although initially highly productive, was one of the quickest ways of depleting the already meagre calcium capital of the soil, inevitably leading to reduced production.

As no timber crop can be grown upon these soils without making relatively heavy demands of certain nutrients, it appeared more economic to increase the levels of these nutrients in the soil, well before their deficiency reduced timber production.

Studies have been made upon soils within the area which have been so treated and where increased timber yield is being obtained from the pioneer crop.

But much experimental work is desirable to ascertain the best ways of carrying out permanent site improvement.

Part III. Reports on Results of Individual Investigations.

PRODUCTION OF SEED BY FOREST TREES IN BRITAIN

By J. D. MATTHEWS
Forest Geneticist

THE objects of this paper are: first, to give a short account of some of the factors affecting the flowering and fruiting of forest trees; and second, to summarise five years of observations on the flowering and fruiting of the more important tree species in Britain. The data on beech and Corsican pine are the result of regular observations on the flowering and fruiting habits of certain individual trees, woodlands and plantations. The data given for the other species are based upon general observations made during the search for "plus" stands and "plus" trees for use in tree breeding. With the exceptions of information published by Hanson (1934), Anderson (1950), the Forestry Commission (1951), Hyde (1951) and Gray (1953), there is surprisingly little information available about the flowering and fruiting of forest trees in Britain.

Outline of the Process of Flowering and Fruiting

The first essential for the production of seed is that the tree must attain a "ripeness to flower" or condition of internal readiness to form flower buds. The production of flower buds then follows when, among other things, certain requirements of temperature, light and nutrition are satisfied. Once flowering and fruiting have commenced subsequent seed crops show periodic trends, seed production being limited and sporadic in youth, more plentiful and regular in middle age and falling off gradually in old age. The process of seed formation has seven distinct stages, commencing with the enlargement of the inflorescence in the flower bud, followed by flowering, pollination, fertilization, growth and differentiation of the embryo, growth of seed and fruit to maturity, and finally ripening of the fruit. The developing seed has many enemies which include adverse weather, insects, animals and birds, all of which reduce the high potential production represented by the flower buds to a comparatively low production of well-filled, viable seed.

Factors affecting the Formation of Flower Buds in Trees

(1) Attainment of "Ripeness to Flower"

All plants (including trees) must undergo a certain amount of vegetative growth before they will respond to any stimulus for flowering (Hamner 1948). When the tree is physiologically prepared for flowering some of the resting buds (which are formed early in the growing season by most tree species) are altered in their rudimentary state so that they become male, or female, or else hermaphrodite "perfect" flowers, on opening in the following spring (Baldwin 1942). The length of the "juvenile" or non-fruiting phase in forest trees depends on a number of factors. Most are environmental but some are inherent.

Vigour of Growth. A few individual trees may flower abnormally early (individuals of *Pinus contorta* and birch which flower at two or three years of age have been found in Britain) but for the majority of trees a certain minimum age and size is reached before they become "ripe to flower". Vigorous crown development which enables the tree to assimilate storage food is also necessary (Baldwin 1942). The records and observations of Büsgen and Münch (1929), Langner (1951) and others suggest that, in general, vigorous healthy trees are the first to bear flowers and fruits. This is confirmed by observations on Scots and Corsican pine and Japanese larch in Britain.

Environmental Conditions. Baldwin (1942) states that trees on south slopes may flower and fruit before trees on north slopes. Büsgen and Münch (1929), Baldwin (1942) and Schlich (1910) are agreed that trees in the open or on the edges of plantations, that is, trees in sunny positions, come into flower earlier in life than those grown in a close stand or in shade. Evidence in support of these general statements has been gathered from many young plantations of the larches, pines and spruces in Britain.

Instances of early flowering and cone bearing due to unfavourable conditions are also on record. Flower production soon after planting in Scots pine and larches has been attributed to accidental root pruning during the removal from the nursery and planting in the field, or to a long, dry summer soon after planting, or to a disturbance in normal nutrition due to transfer from a rich nursery soil to a sterile site (Baldwin 1942). Enormous crops of flowers and fruits are frequently borne by distinctly unhealthy or badly injured trees—the so-called "distress" cones or fruits. Seeds of such abnormal crops are, however, usually below average in size and viability.

Adaptation to the Site. The ability to reproduce and perpetuate itself is a fairly good criterion of the adaptation of a species (Baldwin 1942). Exotics and trees originating from places with climates differing greatly from that of the planting site may show their poor adaptation by relatively poor seed production. Corsican pine in Britain growing at elevations of over 600 feet and on sites with a mean annual rainfall of over forty inches rarely produces flowers and when flowering and fruiting does occur both cones and seed are undersized.

Inherent Differences Between Species. For most species there is evidence of variation in inherent capacity for seed production. Pioneer, light demanding species such as birch and Scots pine come into flower early in life. The more shade enduring beech and the spruces bear later in life and are normally less prolific seeders.

Inherent Differences Within Species. Johnsson (1949) demonstrated that precocious flowering is an inherent character in individual trees of *Betula verrucosa* (=*B. pendula*) and *B. pubescens*. Schröck (1949) found that precocious flowering is also an inherent character in some Scots pine trees. For various reasons very precocious trees of most species are best avoided in seed collection.

Age of First Flowering and Fruiting. The various factors described act together to lengthen or shorten the non-fruiting phase in forest trees. The age of first flowering will therefore vary somewhat but Column 3 in Tables 21 and 22 (see pages 67 to 69) gives the ages at which trees of the more important species normally commence to bear flowers in Britain.

The question is often asked whether viable seed is borne by such young trees. Provided the trees are in good health they are capable of producing viable seed. The lack of fertile seed at an early age is often due to inadequate pollen production. Wareing (1953) states that in Scots pine the first female cones appear at

Table 21

FLOWERING AND FRUIT PRODUCTION CON[illegible]

English Name	Botanical Name	Age of Flowering and Fruiting: First Flowering (Years)	First Good Seed Crop (Years)	Maximum Production (Years)	[illegible]
(1)	(2)	(3)	(4)	(5)	(6)
Scots pine	*Pinus sylvestris* L.	5–10	15–20	60–100	2-3
Corsican pine	*Pinus nigra* var. *calabrica* Schneid.	20–25	25–30	60–90	1-5
Lodgepole pine	*Pinus contorta* Douglas ex. Loud.	5–10	15–20	*30–40*	1-3
Mountain pine	*Pinus mugo* Turra	5–10	15–20	*30–40*	2-3
European larch	*Larix decidua* Mill.	10–15	25–30	40–60	1-5
Japanese larch	*Larix leptolepis* Murr.	5–10	15–20	40–60	1-5
Hybrid larch	X *Larix eurolepis* Henry	5–10	15–20	40	1-5
Douglas fir	*Pseudotsuga taxifolia* Rehder	15–20	30–35	50–60	1-7
Norway spruce	*Picea abies* Karst.	20–25	30–35	*50–60*	1-5
Sitka spruce	*Picea sitchensis* Carr.	20–25	30–35	Begins at 40–50	1-5
Serbian spruce	*Picea omorika* Bolle	15–20	20–25	40	1-3
Common silver fir	*Abies alba* Mill.	25–30	—	*40–60*	–
Grand fir	*Abies grandis* Lindl.	30–35	40–45	—	1-5
Noble fir	*Abies procera* Rehd.	25–30	30–35	*40–60*	[illegible]
Western hemlock	*Tsuga heterophylla* Sarg.	15–20	25–30	40–60	[illegible]
Western red cedar	*Thuja plicata* D. Don	10–15	20–25	40–60	[illegible]
Lawson cypress	*Chamaecyparis lawsoniana* Parl.	5–10	20–25	40–60	[illegible]

Notes: Column 3. Seed crops at these ages are normally small, and may be lacking altogether

Column 5. The figures in italics are based upon limited data.

Column 6. The figures refer to the intervals between good seed years. In Scots pine for example 2–3 years of relatively poor production will generally follow a good seed year.

F CONIFEROUS TREES IN BRITAIN

ntervals Between:		Time of Flowering	Recommended Time of Seed Collection			Notes
ood one rops	Poor to Moderate Cone Crops		Earliest	Normal	Latest	
(6)	(7)	(8)	(9)	(10)	(11)	(12)
-3	Some seed most years	May	November	January	February*	A good seed producer.
-5	—	May/June	December	January	February*	Most seed produced in S.E. and E. England.
-3	Some seed most years	May	December	January	February*	Good seed producer.
-3	Some seed most years	May	November	January	—	A good seed producer.
-5	—	Mar./April	October	November	December*	Flowers often damaged by frost.
-5	—	Mar./April	—	September	October	Flowers often damaged by frost.
-5	—	Mar./April	—	September	—	Flowers often damaged by frost.
-7	—	April	September	September	October*	
-5	—	May	—	October	December*	
-5	Marked periodicity	May	—	September	—	
3	—	April/May	—	September	—	Shows promise of being a good seed producer.
-	—	May	August	Aug./Sept.	—	
5	—	May	August	Aug./Sept.	September	A poor seed producer so far.
	—	May	August	Aug./Sept.	September	
	—	April	—	September	October	
	Some seed most years	Mar./April	August	September	September	A good seed producer.
	Some seed most years	Mar./April	August	September	September	A good seed producer.

Column 8. March/April means end of March beginning of April.

A dash means no data are available.

*With these conifers, it is possible to collect cones until early spring, but the yield of seed is likely to be lower than that from earlier collections.

FLOWERING AND FRUIT PRODUCTION

Table 22

English Name	Botanical Name	Age of Flowering and Fruiting: First Flowering (Years)	First Good Seed Crop (Years)	Maximum Production (Years)
(1)	(2)	(3)	(4)	(5)
Pedunculate oak	*Quercus robur* L.	25–30	40–50	80–12[illegible]
Sessile oak	*Quercus petraea* Lieb.	25–30	40–50	80–20[illegible]
Red oak	*Quercus borealis* Michx.	—	30–40	—
Beech	*Fagus sylvatica* L.	30–40	50–60	80–20[illegible]
Sycamore	*Acer pseudoplatanus* L.	15–20	25–30	*40–6[illegible]*
Ash	*Fraxinus excelsior* L.	15–20	25–30	*40–6[illegible]*
Birch	*Betula pubescens* Ehrh. } *Betula pendula* Roth. }	5–10	15	20–30
Spanish chestnut	*Castanea sativa* Mill.	—	30–40	—
Common alder	*Alnus glutinosa* Gaert.	5–10	15–20	30
Small leaved lime	*Tilia cordata* Mill.	—	20–30	—
Large leaved lime	*Tilia platyphyllos* Scop.	—	20–30	—

Notes: Column 3. Seed crops borne at these ages are normally small, and may be lacking altogether.
Column 5. The figures in italics are based upon limited data.

about seven years while male cones are not generally found until several years later on the lower older branches. Sitka spruce also exhibits this tendency to produce only female flowers in early life in Britain. In some cases pollination of the young trees can be affected by older trees of the same species growing close by. In such circumstances the number of sound seed is likely to be higher than in even-aged young crops.

Age of First Economic Seed Production. The number of fruits or cones borne by normal young trees is never very large and flowering and fruiting tends to be rather spasmodic. A few more years must elapse after first flowering during which the crowns of the trees develop, the foliage mass increases and the potential flower and fruit bearing area increases. Column 4 of Tables 21 and 22 gives the ages at which what might be termed the first economic crops of seed are borne, that is, good crops of fruit or cones both as regards numbers and yield of well-filled, viable seed.

BROADLEAVED TREES IN BRITAIN

Intervals Between: Good Seed Years	Intervals Between: Poor to Moderate Seed Years	Time of Flowering	Recommended Time of Seed Collection: Earliest	Normal	Latest	Notes
(6)	(7)	(8)	(9)	(10)	(11)	(12)
2-4	Some mast most years	May	September	October	November	A good mast producer.
3-5	—	May	September	October	November	
2-4	—	May	September	October	—	
[illegible]-10	—	April/May	September	October	November	Flowers sometimes damaged by late frosts.
2-3	Some seed most years	April/May	September	Sept./Oct.	October	
3-5	Markedly periodic	April	August (1)	Oct. (2)	November	(1) For immediate sowing. (2) For stratification
1-2	Some seed most years	April	August	Aug./Sept.	September	Good seed producers in Britain.
2-3	—	June/July	—	October	November	A good summer is required to ripen the nuts.
2-3	Some seed	Feb./Mar.	September	October	November	
2-3	—	June/July	—	October	—	
2-3	—	June/July	—	October	—	

Column 6. The figures refer to the intervals between good seed years. In pedunculate oak for example 2 to 4 years of relatively poor production will generally follow a good seed year.

A dash means that no data are available.

Age of Maximum Production. Nisbet (1905) and Schlich (1910) are agreed that the most favourable period of seed production is when trees are nearing the completion of their main growth in height and have begun to expand their crowns, that is, during the period of high volume production. At this stage good soil, warm situation and ample growing space all favour the regular production of seed. Vincent (1940) considered that satisfactory seed production (in Czechoslovakian forests) could best be maintained by repeated heavy thinnings so that the seed trees developed vigorous crowns.

The ages given in Column 5 of Tables 21 and 22 are necessarily very provisional because of the lack in Britain of older age-classes in many species.

(2) The Initiation of Flower Buds

The question what causes one bud to become a flower bud and another a vegetative bud cannot yet be answered but some of the more obvious controls can be indicated. The principal factors involved appear to be temperature, light, water supply and nutrition.

Effects of Temperature on Flower Initiation. A certain minimum degree of heat is apparently necessary for flower bud formation, probably higher than that required for the formation of vegetative buds. Scots pine in Norway apparently requires summer temperatures 3°F. to 4°F. higher for successful fruiting than for vegetative development (Hagem 1917). Tirén (1935) found that high summer temperatures have strong effects on flower bud setting by Norway spruce in Sweden. High July temperatures appear to exert the greatest influence. Higher than average June and July temperatures are necessary for flower bud formation by beech in Sweden (Lindquist 1931) and higher than average temperatures and incidence of sunshine in July also favourably influence flower bud initiation of beech in Britain.

Effects of Light on Flower Initiation. One of the major external factors affecting the growth of plants is the length of day or photoperiod. It is probable that the great majority of plants, both herbaceous and woody (Wareing 1948), are sensitized and react to recurrent daily light periods. This response is called photoperiodism. Day length may modify any or all of the structural parts of a plant but interest is chiefly centred on its influence on the formation of flowers and development of fruits and seeds. Langlet (1942) reports from Sweden that northern strains of Scots pine grown under the shorter days of more southern latitudes produce female flowers at an earlier age than in their normal region of growth.

The influence of day length is however modified and sometimes counteracted by other environmental factors particularly temperature.

The exact mechanism of photoperiodism is not yet known. It is however fairly certain that as a result of the photoperiodic stimulus a hormone-like substance is formed in the leaves. From there it moves to the growing points, resulting in the initiation of flower primordia.

Effects of Nutrition on Flower Initiation. Kraus & Kraybill (1918) suggested that the relationship between the amounts of vegetative and reproductive growth is determined by the ratio of carbohydrate and nitrogen substances present within the plant and available for its nutrition—that is on the value of the carbohydrate/nitrogen ratio. A great deal of work was done to develop the concept of the C/N ratio, and until recently it was assumed that a high carbohydrate/nitrogen ratio was a cause of flowering. Carbohydrate accumulation depends primarily on the supply of nutrients from the soil, the amount of light reaching the crown of the tree and the leaf area of the crown. The leaves are obviously important for the manufacture of carbohydrates. They are also a source of a flower-inducing hormone the formation of which has its origin in the photoperiodic stimulus.

Recent research (Murneek 1948, Gregory 1953, Stoughton 1954) suggests that the initiation of the flowering process precedes the accumulation of carbohydrates and that the variations in the C/N ratio are a consequence and not a cause of flowering. The C/N ratio and flowering are however connected and the concept retains some of its usefulness.

Several environmental factors may check growth and lead to carbohydrate accumulation. Flowering and fruiting also take place provided vegetative growth is not seriously retarded or stopped. A reduction of the water supply in summer is frequently associated with flower bud formation and fruit production especially in beech where the correlation of summer droughts with mast production extends over a century (Büsgen & Münch 1929). High rainfall during June, July and August appears to be detrimental to flower bud initiation in oak and beech. Seed production also makes great demands on the starch reserves of the stems of trees (Phillips 1938) and a heavy seed crop one season adversely affects fruit bud formation for the following year.

The nutrient elements most closely connected with flowering and fruiting appear to be nitrogen and phosphorus. Applications of complete (N.P.K.) fertilizers have also increased the flowering and fruit production of species of pine (Gemmer 1932, Wenger 1953) and also of rubber trees (Haines 1946). Toumey (1928) states that trees growing in soils low in nitrogen and phosphate produce poor seed crops.

Girdling or banding of the stems of Scots pine, Corsican pine (Holmes and Matthews 1951) and beech, and removal of the terminal buds of young Scots pine (Wareing 1953, Busse 1924) have resulted in increased flowering and fruit production.

(3) The Formation of Flower Buds and Subsequent Growth of the Inflorescence

Gardner (1939) considered that there is considerable variation in the time when flower buds are formed in fruit trees. Generally they are differentiated during the summer and autumn before the buds open. The exact time of differentiation depends, among other things, on the species, seasonal conditions, moisture supply, growth conditions and position on the tree. The decisive period for many tree species is probably July or August (Baldwin 1942). According to Tirén (1935) the formation of flower buds of Norway spruce normally takes place during August in Sweden. The flower buds of beech are recognisable in September and are probably formed in August in Britain. The buds which will bear male flowers in Scots and Corsican pine can be readily identified in September and October and flower buds of the larches can also be easily recognised at that time.

(4) Periodicity

Trees which bear heavy crops of seed in one year and then sparsely or none for several years are said to show periodicity in seed bearing. Two kinds of periodicity are recognised—an inner or spontaneous periodicity and an induced one (Baldwin 1942). The existence and importance of an inherent periodicity is very difficult to determine. Biennial bearing in fruit trees has received considerable attention and there is still divergence of opinion about the fundamental causes of this phenomenon (Singh 1948). Tirén (1935) showed that in Norway spruce flower bud formation reduces the potential foliage producers (vegetative buds) in that season so that the possibilities of flower bud formation are reduced in the next year.

Induced periodicity depends upon "ripeness to flower" and the periodic occurrence of the external conditions favourable to fruiting. The importance of temperature, light and nutrition have been discussed and it remains to summarise their effects in terms of periodicity.

Having once borne flowers, fruits and seed the length of time elapsing before a seed tree is again ready to produce is apparently shortest when the fertility of the soil is relatively high and the crown has ample space for a speedy recovery of the foliage lost to reproduction. Favourable weather is the next essential and it appears that warmer, dryer and sunnier-than-average summer weather is a necessary prelude to renewed flower production.

The figures given in Columns 6 and 7 of Tables 21 and 22 are mainly derived from seed production data for the period 1921 to 1950. These data were gathered from four main sources:

(*a*) The Reports of the Phenological Observations in the British Isles published by the Royal Meteorological Society.

(*b*) The Annual Reports of the Forestry Commissioners.

(*c*) The Forester's Records published by the Royal English Forestry Society.

(*d*) Information published by Nisbet (1905), Schlich (1910) and papers by Watt (1925), Dallimore (1935), and Hyde (1951).

Seed crops are not necessarily uniform throughout the country in the same year. Severe spring frosts in parts of North East England in May 1948 created a local shortage of beech nuts which contrasted sharply with the generally high level of the 1948 beech mast over the country as a whole. In 1949 Corsican pine of seed bearing age produced cones on almost every site on which it was growing in Britain, but good seed production was mainly restricted to South-East and Eastern England.

For some species there are areas in which flowering, fruiting and seed production are noticeably better than elsewhere. Scots pine flowers and cones well in Morayshire, Corsican pine bears seed regularly in Suffolk, and beech appears to produce mast more regularly on the South Downs and Cotswolds than elsewhere. Within these variations over the country as a whole there are also individual variations. Individual trees of similar size on the same site vary greatly in their flowering and fruiting.

The Process of Seed Formation

(1) Flowering

Column 8 of Tables 21 and 22 shows the normal times of flowering of the more important tree species in Britain. It will be seen that the majority flower during March, April and May. The precise time of pollen dispersal and receptivity of female flowers for a given species varies from place to place and from year to year. A detailed picture of the daily and annual variation in time of pollen dispersal by oak, ash, beech, birch, alder and pine is given by Hyde (1952).

The potential danger of damage to flowers by spring air frosts will also be apparent from an examination of the data given in Tables 21 and 22. The flowers of the larches and beeches are often damaged by frost while those of the pines and especially Corsican pine are less frequently affected.

(2) Pollination

The importance of adequate pollination in the development of viable seed by forest trees has not been sufficiently stressed in the past in Britain. Cross pollination is the general rule and a considerable number of forest trees are more or less self sterile. Single, isolated trees such as are found in arboreta either produce empty seed or a variable amount of self-fertilization occurs which often, but not always, has a depressing effect on the vigour of the seedlings raised from the viable seed. Single isolated trees should therefore be avoided in normal seed collections and small groups of trees are usually more valuable as seed sources than very scattered specimens.

The trees listed in Tables 21 and 22 (with the exception of ash, lime and sycamore) are monœcious—that is the male and female flowers are borne separately on the same tree. The male and female flowers may be intimately mixed over the whole crown of the tree as on the oaks, beech, the larches and

Douglas fir, or tend to be separated. This latter condition is most strongly developed in the silver firs and spruces in Britain, the female flowers being mainly borne in the upper parts of the living crown while the male flowers predominate in the middle and lower parts. The pines vary considerably but generally female flowers predominate on the uppermost whorls of branches and male flowers on the lower branches with a wide middle zone of intimate mixture.

Some ash trees bear only male or female or hermaphrodite flowers while others represent seven transitional forms of various kinds. For example trees bearing male and female and hermaphrodite flowers are occasionally found (Larsen 1945).

Many forest trees exhibit the condition known as dichogamy in which the male and female elements on the same tree mature at different times. If the female elements mature first the tree is said to exhibit protogyny and this is apparently a common condition among the pines, spruces and larches in Britain. When the pollen is released before the female flowers on the same tree are receptive the tree is said to be protandrous. Nielsen and Schaffalitsky (1954) examined the flowering behaviour of beech in Britain and Denmark and found that although beech is normally protogynous, protandrous individuals do occur. Protandry also appears to be less common than protogyny in other species but has been observed in Britain in Scots pine, alder and, depending on the spring weather, in larch by Leven (1951).

The dispersal of pollen is somewhat dependent on the weather prevailing at the time of flowering. The failure of Douglas fir seed crops in Western North American in some years has been attributed by Allen (1951) to bad weather at pollination time. In the case of the entomophilous or insect pollinated species such as sycamore and lime good flying weather for insects is required. Thus the need is for bright, dry and fairly calm weather. For the anemophilous or wind pollinated trees (that is for the majority of the major species) fresh, dry, warm and moderately windy weather is required. Pollen grains absorb moisture very rapidly and travel less far when wet than when dry. The shedding of pollen by pine and birch is very rapid when conditions are favourable and in a given stand of birch in Finland (Sarvas, 1952) the peak of dispersal rarely lasts longer than three or four days.

Many cases are on record of small amounts of air-borne tree pollen travelling great distances from the source (Erdtmann, 1943) but several workers have shown that the bulk of air-borne pollen produced by a given tree falls at surprisingly short distances from the source. Wright (1952) found that the incidence of the relatively large pollen grains of Douglas fir and Norway spruce was *nil* and *low* respectively at distances greater than 150 feet from individual trees. Langner (1953) studied the range of pollen dispersal in Norway spruce by collecting seed from trees with normal foliage growing near to golden foliaged trees. The results suggested that pollination is mainly effected by trees in the immediate vicinity of the seed tree. Buell (1947) found that the quantity of pollen falling to the ground at a quarter of a mile from a stand of *Pinus echinata* was only ten per cent of that falling within the forest. Observations in North-Eastern U.S.A. (North-Eastern 1950) make it clear that airborne pollen of species of spruce, oak and pine travels only short distances in quantity and that distances of only a few hundred feet between seed trees may be the limiting factor in the production of viable seed. Wright (1953) found that pollen dispersion distance was not greatly affected by average wind velocity and that size of pollen grain had a slight effect on dispersion distance. Wright's data fitted best with calculations based upon air turbulence and this appears to be important in both dispersing and depositing pollen.

Considerable quantities of pollen are produced by trees with well developed crowns. One object of thinning potential seed bearers is to increase the production of male flowers which (as is also the case with female flowers) are more numerous on isolated trees than on trees in close plantations. Hyde (1951) found that pollen output and subsequent seed crops are often closely related in Britain.

The production of cones and fruit of normal size and appearance is not in itself a proof of the presence of viable seed. Parthenocarpy, i.e. the formation of fruit without fertilization and without seeds or with embryo-less seeds occurs in beech (Nielsen and Schaffalitsky 1954), Douglas fir (Allen 1942, Duffield. 1950), the larches (Larsen 1937) and in other tree species.

(3) Fertilization

For the formation of viable seed pollination is, under normal circumstances, followed by fertilization. The lapse of time between pollination and fertilization is usually short but in the pines the interval is approximately one year. The actual fertilization process in trees is similar to that in most of the higher plants.

(4) Ripening of Fruit and Seed and Seed Collection

The spells of warm, dry, sunny weather which favour the initiation of flower buds and the accumulation of storage food also favour the maturing of the fruit and seed. Considerable variation in seed quality has been found between woodlands and plantations of the same species in Britain, and where possible it is desirable to make a preliminary seed examination before large-scale seed collection begins. In conifers, tests can be made in the field by splitting sample cones lengthwise and examining the seed. In this way some idea will be obtained of the proportion of sound seeds per cone and of the maturity of the seed. (Holmes 1952.)

The precise time of seed collection depends on the weather conditions of the year and also on the local climatic conditions in Britain. In conifers collection should begin late enough to allow the cones to turn brown naturally and yet be in advance of the beginning of seed dispersal. In broadleaved species such as oak, beech and sweet chestnut collection should begin when the first full nuts are found on the ground. Ash can be gathered in summer for direct sowing or in autumn for stratification for eighteen months.

Although few definite rules can be laid down about time of collection it can be said that most collection operations begin too late rather than too early (Baldwin, 1942).

Columns 9, 10 and 11 of Tables 21 and 22 combine direct observations and the recommendations of several authors on the earliest, normal, and latest times to collect seed in Britain. These times of collections have also been confirmed by six experienced foresters—three in Scotland and three in England.

Summary and Conclusions

The achievement of a condition of internal readiness to form flowers is governed by vigour of growth, environmental conditions, adaptation to the site and inherent tendencies. The effect of these factors can be expressed in terms of age.

The production of flower buds is apparently dependent upon favourable conditions of temperature, light and nutrition, in other words on favourable climatic and growth conditions. Once flowering and fruiting have commenced subsequent seed crops show periodic trends mainly due to external weather and growth conditions.

It must be stressed that comparatively little is known of the great complex of factors leading to the production of flower buds and subsequently of fruit and seed. This much seems clear however. A tree must be in good health to produce abundant flower buds and regular crops of well-filled viable seed.

Attention is drawn to a number of factors affecting the formation of fruit and seed. Late spring frosts cause damage to developing flowers buds; favourable weather is required at pollination time; adequate pollination followed by fertilization is necessary for the production of well-filled viable seed, and spells of warm, dry sunny weather are needed to ripen fruits and seeds.

The irregularity of good and abundant seed years of the major forest tree species in Britain during the past thirty years suggests that it is not possible to predict future seed crops with any certainty. There has been a good run of seed years during the ten years 1941 to 1950 but the period 1931-1940 was a less favourable one and the occurrence of a similar run of cool, wet and dull summers such as were experienced in that decade is a possibility in the future.

Some recommendations for ensuring better seed supplies can be made on existing evidence.

(*a*) Full advantage should be taken of good seed years in all species because the highest proportion of well filled viable seed is produced in such years.

(*b*) Better seed collection methods should be developed both for collection from standing trees and from the ground (as in beech and oak). Collection from very tall standing trees will probably only be economic in good seed years.

(*c*) Certain parts of existing woodlands and plantations of seed bearing age should be set aside and thinned rather more heavily than normal to increase the seed production. The size, shape and treatment of such "seed stands" should conform to local silvicultural needs.

As the existing young plantations of many species grow older the seed supply problem in Britain will tend to become easier.

REFERENCES

ALLEN, G. S. (1951) — Making the most of the Cone Crop. *British Columbian Lumberman* 35, 8 (1951), p. 71.

ALLEN, G. S. (1942) — Parthenocarpy, Parthenogenesis and Self Sterility of Douglas fir. *Journal of Forestry*, 40 (1942), 642-644.

ANDERSON, M. L. (1950) — *The Selection of Tree Species.* Oliver & Boyd, Edinburgh, 1950.

BALDWIN, H. I. (1942) — *Forest Tree Seed.* Chronica Botanica. Waltham, Mass., U.S.A.

BUELL, M. F. (1947) — Mass Dissemination of Pine Pollen. *J. Elisha Mitchell Sci.*, 63, 1947.

BÜSGEN, M., and MÜNCH, E. (1929) — *The Structure and Life of Forest Trees.* London, 1929 (English translation by T. Thomson).

BÜSSE, Dr. (1924)	Flowering and Fructification of Artificially Injured Pines. *Forstw. Centralb.*, 8 (1924), 325-332.
DALLIMORE, W. (1935)	Notes on the Dry Seasons of 1933-1934. *Quarterly Journal of Forestry*, 29 (1935), 115-117.
DUFFIELD, J. W. (1950)	Techniques and Possibilities for Douglas fir Breeding. *Journal of Forestry*, 48, 1 (1950), 41-45.
ERDTMANN, G. (1943)	*An Introduction to Pollen Analysis.* Chronica Botanica. Waltham, Mass., U.S.A.
FORESTRY COMMISSION (1951)	*Collection and Storage of Acorns and Beech Mast.* Forestry Commission Leaflet 28. London. H.M.S.O., 1951.
GARDNER, V. R. BRADFORD, F. C., and HOOKER, H. D. (1939)	*The Fundamentals of Fruit Production.* McGraw Hill, London. 1939.
GEMMER, E. W. (1932)	Well Fed Pines Produce More Cones. *Forest Worker*, 8 (1932), 15.
GRAY, W. G. (1953)	*Nursery Notes on Broadleaved Trees.* Forestry Commission Research Branch Paper No. 10. 1953 (Departmental Circular).
GREGORY, F. G. (1953)	The Control of Flowering by Day-length and Temperature. Part I. *Journal of the Royal Horticultural Society* 128, 9, 1953. 313-323.
HAGEM, O. (1917)	*Furuens og Granens Frøsaetning i Norge.* Bergen, 1917.
HAINES, W. B. (1946)	Manuring *Hevea*: IV.—Conspectus of Experimental Improvements achieved in Mature Stands at the end of Ten Years, with a special note on Seed Production. *Emp. Journ. Exp. Agric.*, 14, 56 (1946).
HAMNER, K. C. (1948)	Factors Governing the Induction and Development of Reproductive Structures in Plants. *Symposia of the Society for Experimental Biology II. Growth* 104-116. Cambridge, 1948.
HANSON, C. O. (1934)	*Forestry for Woodmen.* Oxford, 3rd Edition, 1934.
HOLMES, G. D., and MATTHEWS, J. D. (1951)	*Girdling or Banding as a means of Increasing Cone Production in Pine Plantations.* Forestry Commission Forest Record No. 12 (1951). H.M.S.O., London.
HOLMES, G. D. (1952)	Forest Tree Seed Investigations. *Report on Forest Research for year ending March,* 1951. London. H.M.S.O., 1952.
HYDE, H. A. (1951)	Pollen Output and Seed Production in Forest Trees. *Quarterly Journal of Forestry*, 5, 3 (1951), 172-175.
HYDE, H. A. (1952)	Studies on Atmospheric Pollen, V. A Daily Census of Pollen at Cardiff for Six Years 1943-8. *The New Phytologist*, 51, 3 (1952), 281-293.
JOHNSSON, H. (1949)	Hereditary Precocious Flowering in *Betula verrucosa* and *B. pubescens* . *Hereditas Lund*, 35 (1), 1949, 112-114 (For. Abs. 10-2461).
KRAUS, E. J., and KRAYBILL, H. R. (1918)	Vegetation and Reproduction with special reference to the Tomato. *Bull. Ore. Agric. Exp. Sta.*, 149 (1918).

LANGLET, O. (1942) Photoperiodismus bei der gemeinen Kiefer (*Pinus sylvestris L.*). *Medd. Fran. Statens Skogsförsöksanst.* Stockh., 33 (1942-3), 295-327.

LANGNER, W. (1951) Kreuzungsversuche mit *Larix europaea* D. C. und *Larix leptolepis* Gord. *Zeitschrift fur Forstgenetik and Forstpflanzenzüchtung*, 1, (1) 1951.

LANGNER, W. (1953) Eine Mendelspaltung bei Aurea-Formen von *Picea abies* (L.) Karst. Als Mittel zur Klärung der Befruchtungsverhaltnisse in Walde. *Zeitschrift fur Forstgenetik und Forstpflanzenzüchtung*, 2, 3, 1953, 50-51.

LARSEN, C. S. (1937) The employment of Species Types and Individuals in Forestry. *Royal Veterinary & Agricultural College, Copenhagen. Year Book*, 1937.

LARSEN, C. S. (1945) Ash Flowering and Improvement. *Dansk Skovforen. Tidsskr.*, 30 (3), (1945), 48-89.

LEVEN, G. (1951) Flowering Times of Japanese larch (*L. leptolepis* Murray) and European larch (*L. europaea* D.C.). *Scottish Forestry*, 5, 2 (1951).

LINDQUIST, B. (1931) Den Skandinavisker Bogskogens Biologi. *Svenska Skogsforen Tidskr.*, 3 (1931), 179-532.

MURNEEK, A. E. (1948) *Nutrition & Metabolism as related to Photoperiodism. Vernalization & Photoperiodism.—A symposium.* Chronica Botanica. U.S.A., 1948.

NIELSEN, P, and SCHAFFALITSKY, M. (1954) Flower Observations & Controlled Pollination in *Fagus*. *Zeitschrift für Forstgenetik und Forstpflanzenzüchtung*, 3, 1, 1945, 6-17.

NISBET, J. (1905) *The Forester*, London, 1905.

NORTH-EASTERN (1950) Effective Pollination Distances. *North-Eastern Forest Experiment Station, U.S.A. Annual Report*, 1949-1950.

PHILLIPS, J. (1938) Depletion of Starch from Timber. *Forestry*, 12 (1938) 15-29.

SARVAS, R. (1952) On the Flowering of Birch and the Quality of Seed Crop. *Communications Instituti Forestalis Fennica*, 40, 7, 1952.

SCHLICH, W. (1910) *Manual of Forestry*, II, 4th Edition, London, 1910.

SCHRÖCK, O. (1949) Die Vererbung der Frühblüte der Kiefer. *Zuchter*, 19, 8/9 (1949), 247-254 (For. Abs., 12-1764).

SINGH, L. B. (1948) Studies in Biennial Bearing II. A review of the literature. *The Journal of Horticultural Science.* XXIV, 1 (1948), 45-65.

STOUGHTON, R. H. (1954) Some aspects of growth and development in the fruit plant. *Annual Report* 1953, *East Malling Research Station.* 51-59.

TIREN, L. (1935) Om Granens Kottsattning dess Periodicitet och Samband med Temperature och Nedelbörd. *Med F. Statens Skogsförsöksanstalt*, 28 (1935), 413-524.

TOUMEY, J. W. (1928) *Foundations of Silviculture on an Ecological Basis.* New York, 1928.

VINCENT, G. (1940) Can Silvicultural Measures Stimulate Fructification of Trees. *Lesnicka Prace*, 19, 5 (1940), 221-231.

WAREING, P. F. (1948) Photoperiodism in Woody Species. *Forestry*, 22 (1948), 211-221.

WAREING, P. F. (1953) Experimental Induction of Male Cones in *Pinus sylvestris*. *Nature*, 171 (1953), p. 47.

WATT, A. S. (1925) On the Ecology of British Beechwoods with Special Reference to their Regeneration, Part II. Sections II & III. *Journal of Ecology*, XIII (1925), p. 27.

WENGER, K. F. (1953) The Effect of Fertilization and Injury on the Cone and Seed Production of Loblolly pine trees. *J. For.*, 52, 8 (1953), 570-573.

WRIGHT, J. W. (1953) Pollen Dispersion Studies: Some Practical Applications. *Journal of Forestry*, 51, 2, 1953, 114-118.

EAST SCOTLAND SCOTS PINE SEEDLING PROVENANCE TRIAL

By G. BUSZEWICZ, *Experimental Officer;* M. V. EDWARDS, *Silviculturist* (North), and J. D. MATTHEWS, *Geneticist*

IN the autumn of 1951 Scots pine seed was collected from a selection of plantations in eastern Scotland. These stands have been allocated to a number of seed collection zones which are intended as a guide for the movement of Scots pine planting stocks. The seed is required to form plantations in places where pine is very scarce at present, and it is intended that stocks raised from seed gathered in places roughly equivalent in climate and other site characteristics shall be used.

At the same time the opportunity was taken to carry out a provenance trial with some of the seed. This was sown in a replicated experiment at Teindland Woodland Nursery in Morayshire. In this instance the plantations from which the seed came have been classified according to the exposure zones of M. L. Anderson (1930). The vigour and habit of growth and other characteristics of the plantations have also been assessed by visual scoring and they have been classed as either B (normal) or B+ (better than normal). The weight of 1,000 pure seeds of each provenance, and the mean height of the one-year-old seedlings, have been correlated with each other and with the elevation of the parent stand.

First Year in the Nursery (1952)

The seed of the different origins varied considerably in size and germination capacity. As a result of data obtained from the standard tetrazolium test, the seed was divided into two groups, the better group being sown at 495 feet square per pound and the poorer group at 405 square feet per pound of seed. Allowing for a sixty-six per cent success of the viable seed, it was estimated that these rates of sowing would yield between eighty and 120 plants per square foot at the end of the season. These figures were very approximate, especially on account of the high percentage of under-developed embryos in some seed lots.

The actual results at the end of the first year showed that most seed lots had yielded from ninety to 110 plants per square foot. The extremes were sixty-six and 126. On the whole the plants from all origins had reasonably similar conditions in which to develop.

EAST SCOTLAND SCOTS PINE PROVENANCE TRIAL
RESULTS AT THE END OF THE FIRST YEAR

Table 23

Provenance	County	National Grid Reference	Elevation (ft.)	Exposure Zone	Seed Source class	Weight of 1,000 seeds (gms)	Mean ht. of seedlings (inches)
Altyre Estate, Office Wood	Morayshire	38/034557	200	B	B+	6.46	2.3
Crathes Estate, Carleith Wood	Aberdeenshire	37/743975	175	B	B+	6.03	2.3
Glentanar Estate, Bridge of Ess	Aberdeenshire	37/510975	450	D	B+	4.79	2.3
Drummond Hill Forest, Compt. 90	Perthshire	27/785477	650	E	B	6.53	2.3
Orton Estate, Mill Dam and Kennels	Morayshire	38/308548 38/310550	175–200	B	B	5.12	2.0
Ballindalloch Estate Tomfarclas Wood	Morayshire	38/201376	900	D	B	4.86	1.9
Blelack Estate, Aucharran Woods	Aberdeenshire	38/432034	625	D	B+	4.07	2.0
Meggernie Estate, By Gallin Farm	Perthshire	27/537455	750	E	B+	4.34	1.9
Balnaboth Estate	Angus	37/320667	950	C	Felled	5.10	1.8
Rannoch, Dall Estate, Below Creagan-na-corr	Perthshire	27/597546	1100	E	B	4.46	1.7
Ballochbuie, North of Private Road	Aberdeenshire	37/205902	1100	E	B	3.65	1.4
Rannoch Forest, by Allt-na-Bogair	Perthshire	27/597546	1150	E	B	4.30	1.5
	Standard Error of the means						0.08
	Difference necessary for significance at levels of					5%	0.25
						1%	0.34
						0.1%	0.46

Teindland Woodland Nursery, Expt. No. 1 of 1952.

At the end of the first year the mean height of seedlings (see Table 23) showed very highly significant differences between the provenances. The differences between the blocks of the experiment were not significant. The provenances can be grouped into three height classes. Those from Altyre, Crathes, Glentanar and Drummond Hill were significantly taller than the remainder, although these four origins did not differ significantly among themselves. In the middle class Orton, Ballindalloch, Blelack, Meggernie, Balnaboth and Rannoch (Dall), were included. These progenies, although significantly smaller than those in the first group, did not differ among themselves. In the last group, comprising Ballochbuie and Rannoch Forest, the plants were significantly smaller than all other progenies.

These differences were obtained at Teindland, and it does not necessarily follow that the same provenances would prove superior or inferior if the sowings had been made under different conditions.

Results

There are several conclusions to be drawn from this experiment. In the first place, the mean height of the one-year seedlings is highly significantly correlated with the weight of the seed (See Fig. 1). The correlation co-efficient: r=0.60, is significant at the 1 % level of probability. This shows that, on the average, seeds weighing for example 4.0 grams per 1,000 (which is equal to 113 thousand seeds per pound of pure seed) produced seedlings with a mean height of 1.7 inches, while seeds weighing 6.0 grams per 1,000 (equal to seventy-six thousand seeds per pound of pure seed) produced seedlings with a mean height of 2.2 inches.

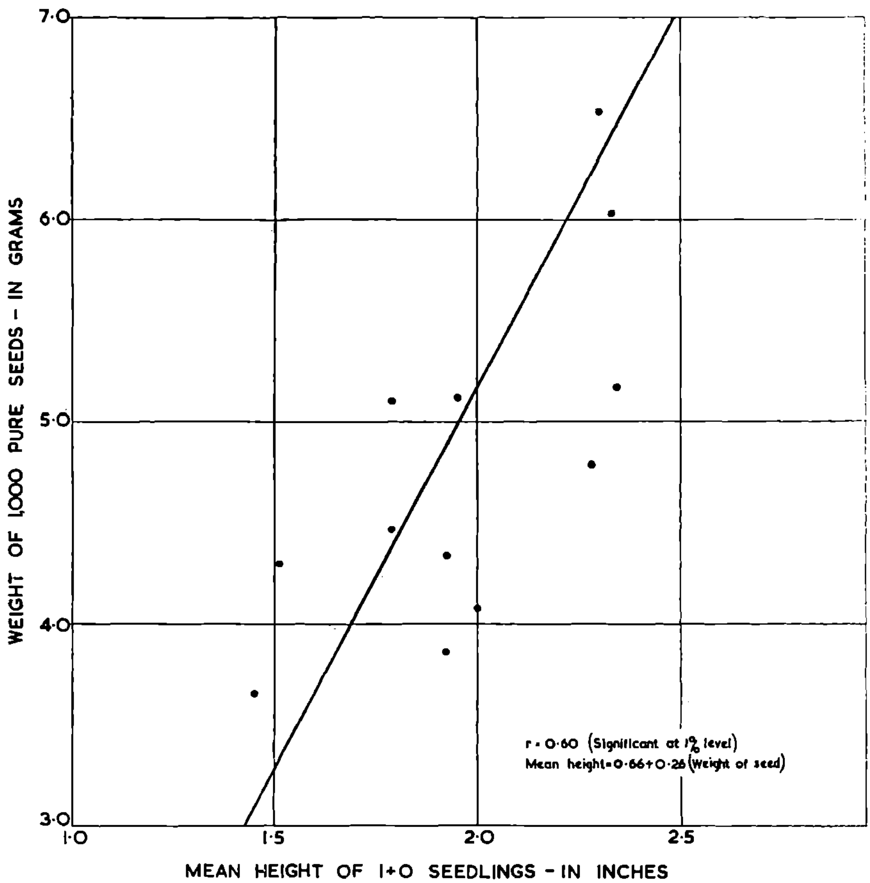


Fig. 1. Relation between Seed Weight and Height of One-Year Seedlings.

The seeds sown in this experiment were from a dozen selected plantations out of some thirty collections made in the East Conservancy. The data from all these collections show that the seed weight is also closely correlated with the elevation above sea level of the parent stand (See Fig. 2). r=—.510, significant at the 5 % level of probability. This shows, that on the average, seed from a stand at elevation 200 feet has a mean seed weight of 5.5 grams per thousand compared to a mean for seed from 1,100 feet of 4.0 grams per thousand.

Furthermore, there is a significant correlation between the percentage of under-developed embryos in the seed and the elevation of the parent stand, the ripening of the seed not taking place fully at higher altitudes. The correlation co-efficient: r=.706 is significant at the 1 % level of probability.

The percentage varies from about five per cent at 600 feet up to twenty and thirty-five per cent at elevations over 1,000 feet (See Fig. 3).

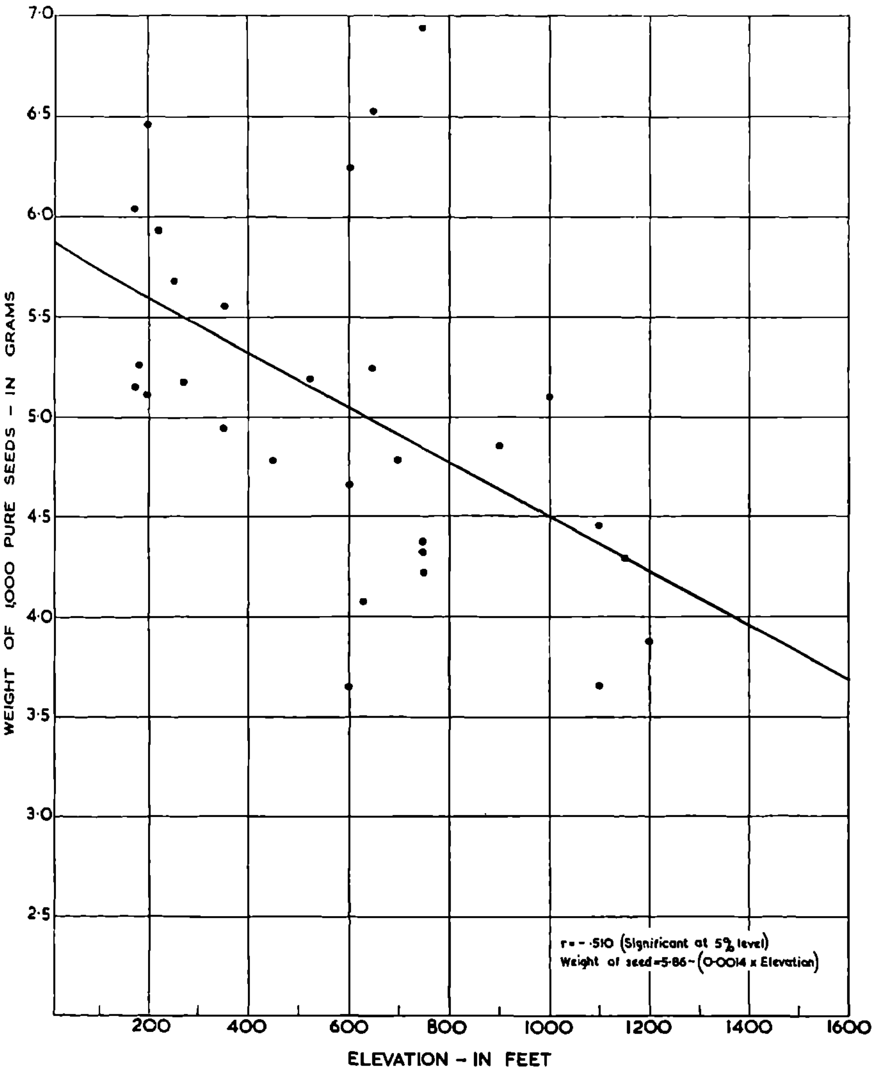


Fig. 2. Relation between seed weight and elevation of seed source.

It follows from these results that seed weight and the exposure zone should be correlated and this appears to be the case (See Fig. 4). Seed collected in zones A to C rarely weighed less than 5.0 grams per 1,000, whereas seed from zones D and E was mostly under that weight.

Further Work

The plants from this experiment have been planted at three different forests at varying elevations and consequently with different climates, namely, Laiken Forest in Nairnshire (Anderson's zone B), Glenisla Forest in Angus (zone C/D) and Glenlivet Forest in Banffshire (zone D/E). The reaction of the provenances to these different sites will be studied as they grow older.

REFERENCE

ANDERSON, M. L. (1930). On the distribution of coniferous quality classes in Scotland. *Scot. For. Journ.*, 44 (1): p. 45-54.

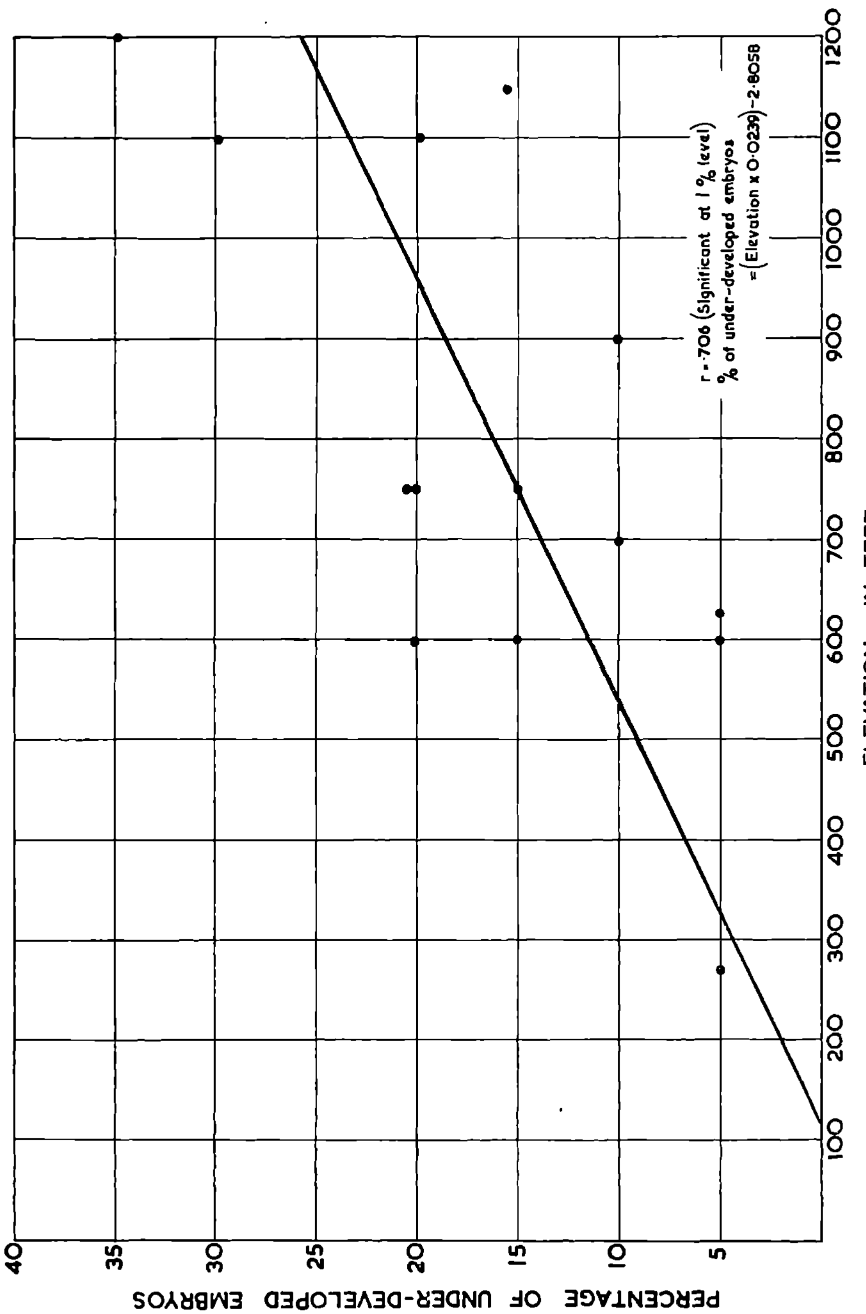


Fig. 3. Relation between Percentage of Under-Developed Embryos and Elevation of Seed Source.

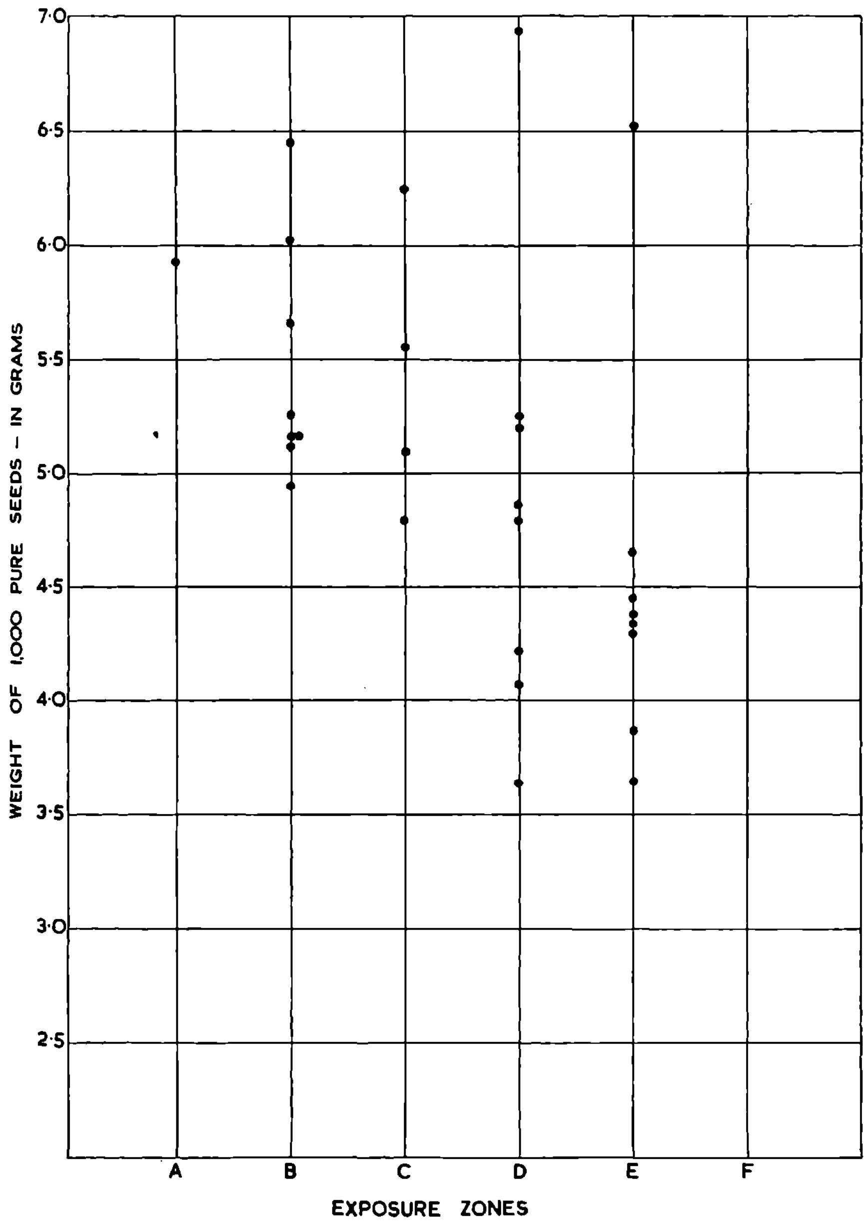


Fig. 4. Relation between Seed Weight and Exposure Zones.

EXPERIMENTS WITH COLD-WET PRETREATMENT AS A METHOD OF INCREASING THE GERMINATION RATE OF SEED OF DOUGLAS FIR, SITKA SPRUCE AND LODGEPOLE PINE

By G. D. HOLMES, *Assistant Silviculturist*
and G. BUSZEWICZ, *Experimental Officer*

SEEDS of many tree species germinate very slowly even under the favourable conditions which can be provided in seed germinators operated under controlled conditions in the laboratory. Such seeds present difficulties not only to the practical forester, but also to the seed analyst who is responsible for carrying out accurate tests of germination quality on samples of seed. A slow rate of germination necessitates taking up valuable germinator space in the laboratory for long periods often at a time when there are large numbers of samples to be tested and germination reports are urgently required. In addition there are practical difficulties in continuing germination tests over long periods owing to the profuse development of saprophytic moulds on seeds under the warm humid conditions in most types of laboratory germinator.

Douglas fir, Sitka spruce and lodgepole pine are extensively used, and all three species exhibit varying degrees of seed dormancy, even between seed lots within each species. Some lots are non-dormant, and others are dormant and will not germinate for long periods unless pretreated. Douglas fir shows the most regular and distinct dormancy, and most seed lots require more than 70 days for full germination under laboratory conditions. Sitka spruce and lodgepole pine are more variable, but generally germinate fully within 60 days. Until recently, all routine germination tests at the Alice Holt laboratory have been continued over 42 days for Douglas fir and Sitka spruce, and 35 days for lodgepole pine, and continuation beyond these periods has resulted in extensive growth of moulds on and around ungerminated seeds. Ungerminated seeds were cut and subjected to a chemical viability test using 2, 3, 5-triphenyl tetrazolium bromide. This permitted estimation of germinative capacity, but the procedure was troublesome and time consuming, as frequently large numbers of seeds remained to be cut and examined at the end of each test.

These difficulties have stimulated interest in methods of pretreatment of seeds of slow germinating species to shorten the period of germination. Barton and Crocker (1948) at the Boyce Thompson Institute have investigated this problem for Sitka spruce and lodgepole pine and showed that germination could be accelerated by stratification of the seeds in granulated peat moss at 41°F for two months. A similar effect was found for Douglas fir and lodgepole pine in early experiments by the Forestry Commission (Steven, 1928). Nursery germination of these species was found to be speeded up after stratification of the seed in moist sand in an open pit for two months before sowing. Soaking seeds in water at normal atmospheric temperatures has been tried with some success. Toumey and Durland (1923) found that soaking seed in water for five days before sowing increased the germination rate of Sitka spruce, similarly Steven (1928) investigated seed soaking and concluded that soaking seed in water at ordinary temperatures for a period not exceeding seven days gives good results with Douglas fir and Sitka spruce. More recently, Holmes (1951) in a series of experiments over four seasons showed for Sitka spruce that there was occasionally a slight increase in the rate of germination following soaking. However, the practical advantages were small and the effect on final germination quite negligible.

Allen (1941) reported that Douglas fir failed to germinate fully even after 120 days in a laboratory germinator. Stratification of the seed in sand for six to ten weeks at a temperature just above freezing point speeded germination very considerably and complete germination could be obtained in the laboratory within about 12 days. Recently, it is understood that Allen has developed a method involving a shorter period of moist prechilling without stratification in sand with good effect (verbal communication).

Rohmeder (1939) investigated moist prechilling of Douglas fir and concluded that although the rate of seed germination was increased by this treatment, its practical value for test purposes was not great, as the test period and the pre-treatment period taken together were just as long as the test period for untreated seeds. He recommends seed presoaking for 24 hours before germination test as a more useful treatment.

Rudolf (1950) and Crossley and Skovs (1951) working with *Picea glauca* seeds showed that seed soaking at temperatures near freezing greatly increased the rate of germination, and gave better results than soaking at normal temperatures.

A series of experiments was started in 1952 to investigate moist prechilling as a seed treatment for Douglas fir, Sitka spruce and lodgepole pine prior to germination testing in the laboratory. A range of treatments were examined as follows.

1. Seed soaked on moist blotting paper at 36°F.
2. Seed soaked totally immersed in water at 36°F.
3. Seed soaked totally immersed in water at room temperature.

Each treatment was applied for set periods from 7 days to 28 days soaking, and seeds were placed under each treatment so that all were ready for sowing on the germinators on the same day. Seeds awaiting treatment were kept under standard storage conditions in air-tight containers, at 2°C (36°F). Several different "lots" or origins of seed were used for each species in the trial in addition to replication of treatments within each seed lot. After pretreatment, germination tests were carried out on Copenhagen tank germinators held at an alternating temperature of 20°C (68°F) at night and 27°C (81°F) during the day, over a period of 42 days, which is the normal test period for untreated seed. After this period all ungerminated seeds were tested by the tetrazolium technique, and the viable seeds added to the final 42 days germination percentage.

Sitka Spruce

The results of germination tests on seeds from the several treatments are presented in Table 24.

GERMINATION PERCENTAGE OF SITKA SPRUCE SEED AFTER 42 DAYS ON A COPENHAGEN TANK GERMINATOR

Table 24

Seed Pretreatment	Period of Treat-ment (days)	Seed Lot Reference-No. 50/272		52/301		51/5		50/257	
		% 42 days	+% viable	% 42 days	+% viable	% 42 days	+% viable	% 42 days	+% viable
0. Dry storage at 36°F	—	71	82	64	70	62	65	11	15
1. Wet Blotters at 36°F	7	70	78	68	76†	62	67	5	6*
" " " "	14	83	88†	70	72	63	69	7	8*
" " " "	21	83	83	75	76†	65	67	11	12
" " " "	28	78	82	71	74	66	70	7	9*
2. Soaking in water at 36°F	7	75	81	59	67	63	65	9	9*
" " " " "	14	80	82	71	72	64	66	7	7*
" " " " "	21	69	70*	71	71	69	69	9	10*
" " " " "	28	82	83	59	59*	62	63	7	7*

Notes: *Significantly lower than value for dry-stored seed at 20 to 1 probability level.
†Significantly higher than value for dry-stored seed at 20 to 1 probability level.
"% 42 days"=actual germination per cent at 42 days.
"+% viable"=actual germination per cent at 42 days + percentage *viable* ungerminated seeds determined by tetrazolium.

None of the seed lots examined showed a high degree of dormancy, and after 42 days an average of only 3% of the viable seeds sown remained ungerminated. Seed pretreatment had no large effect on germination capacity, although there were significant but small increases in the germination of Lot Nos. 50/272 and 52/301 after some of the treatments involving prechilling on wet blotters. There is also some suggestion that soaking in water for periods exceeding 21 days has depressed germination, although this effect is not consistent. Seed Lot No. 50/257 was of very poor quality and all soaking treatments caused a significant depression of germination capacity.

Examination of the percentages of seeds which had germinated after 7, 14, 21, 35 and 42 days on the Copenhagen tank showed that several treatments had greatly increased the *rate* of germination. These effects are presented in Table 25, which shows, for each treatment, the number of days required on the germinator for germination of 90% of the seeds capable of germination. In preparing this table the numbers of seeds which had germinated after 7, 14, 21 and 35 days were expressed as percentages of the numbers of seeds germinating after 42 days for each lot. By using a graphical method and plotting the probits of these percentages over the logarithm of the number of days, it was possible to interpolate the number of days which it took for germination of 90% of germinable seeds.

Lot No. 50/257, which was poor quality seed, showed a slight increase in germination rate after some treatments but its response was small compared with that of the remaining three seed lots. All these lots showed that the most rapid germination occurred after pretreating the seed by soaking in water or on moist blotters at 36°F for 21 days. Pretreatment for shorter periods was less effective. As already stated there is some evidence that soaking in water for such periods may decrease the germination capacity slightly, and in view of this, until further work can be done, the wet blotter technique is regarded as the safer treatment.

THE EFFECT OF SEED PRETREATMENT ON THE RATE OF GERMINATION OF SITKA SPRUCE

Table 25

Seed Pretreatment	Period of Treatment (days)	Number of days required for germination of 90 per cent of seeds capable of germination			
		Lot 50/272	Lot 52/301	Lot 51/5	Lot 50/257
0. Dry storage at 36°F	—	39	36	24	> 40
1. Wet Blotters at 36°F	7	33	35	24	> 40
" " " "	14	25	21	28	31
" " " "	21	<14	<14	<14	25
" " " "	28	18	17	20	40
2. Soaking in water at 36°F	7	27	40	18	21
" " " " "	14	18	16	16	31
" " " " "	21	<14	<14	<14	28
" " " " "	28	<14	15	14	34

Douglas Fir

This species was tested under a similar range of treatments to Sitka spruce, but with the additional treatment of soaking the seeds in water at room temperature prior to germination test. At the time of the experiment only two different seed lots of this species were available, and the results of germination test with these are presented below in Table 26.

GERMINATION PERCENTAGE OF DOUGLAS FIR SEED AFTER 42 DAYS IN A COPENHAGEN TANK GERMINATOR

Table 26

Seed Pretreatment	Period of treatment (days)	Seed Lot Reference No.			
		52/304		52/10	
		% 42 days	+% viable	% 42 days	+% viable
0. Dry storage at 36°F	—	61	74	57	69
1. Wet blotters at 36°F	7	82	87†	58	63
" " " "	14	78	81†	66	71
" " " "	21	79	80†	66	66
" " " "	28	78	80†	67	68
2. Soaking in water at 36°F	7	66	73	59	64
" " " " "	14	75	79	59	60*
" " " " "	21	70	71	62	64
" " " " "	28	73	75	48	50*
3. Soaking in water at room temperature	7	63	71	46	56*
" " " " " "	14	35	41*	38	43*
" " " " " "	21	discarded	as seed det	eriorated	
" " " " " "	28	"	"	"	

Note: Abbreviations are explained under Table 24.

No treatment consistently increased the germination capacity, although soaking on wet blotters at 36°F caused a considerable increase for seed lot

No. 52/304. Soaking in water at 36°F for similar periods had no appreciable effect except in one seed lot in which a slight depression of germination occurred. Soaking in water at room temperature was harmful if continued longer than 7 days. Seeds soaked 14 days showed greatly reduced germination and soaking for longer periods resulted in pronounced seed deterioration and negligible germination. This effect was the same when the water used for soaking remained unchanged throughout the period and when the water was changed regularly every 3 days.

The effects of treatments on the *rate* of germination are summarised in Table 27, which indicates the number of days required to germinate 90 per cent of germinable seeds after each treatment. Those treatments involving soaking in water at room temperature have been omitted from this table.

EFFECT OF SEED PRETREATMENT ON THE RATE OF GERMINATION OF DOUGLAS FIR

Table 27

Seed Pretreatment	Period of Treatment (days)	No. of Days Required for Germination of 90 per cent of Seeds Capable of Germination	
		52/304	51/10
0. Dry storage at 36°F	—	40	53
1. Wet blotters at 36°F	7	27	34
" " " "	14	22	29
" " " "	21	<14	15
" " " "	28	<14	<14
2. Soaking in water at 36°F	7	33	29
" " " " "	14	22	18
" " " " "	21	18	19
" " " " "	28	<14	15

Soaking on wet blotters at 36°F resulted in a great acceleration of germination, and gave more consistent and slightly better results than soaking in water at the same temperature. A period of 21 days pretreatment appears to be the optimal time and with this treatment 90 per cent of germination is complete within 14 days compared with about 50 days required by dry seeds.

Lodgepole pine

Trials were carried out on seed of lodgepole pine in a similar way to Douglas fir. Four seed lots were available for the trial with this species, and the results of germination tests are given in Table 28. It can be seen from this table that the three lots: 50/262, 52/306, and 53/610 showed some slight increases of germination capacity following both low temperature treatments. Lot 49/55 however showed a significant fall in germination following all treatments. The deterioration was considerable in all cases with this seed lot, but the depression was most pronounced following the longer periods of soaking in water at room temperature. It is difficult to explain the odd behaviour of this lot. It may be significant that the seed was five years old having been stored dry at 36°F throughout this period and it was the oldest seed examined in the test. It germinated more rapidly than the three lots of newer seed and showed a correspondingly less pronounced effect of prechilling on its rate of germination.

GERMINATION PERCENTAGE OF LODGEPOLE PINE SEED AFTER 42 DAYS IN A COPENHAGEN TANK GERMINATOR

Table 28

Seed Pretreatment	Period of Treatment (days)	Seed Lot Reference No.							
		49/55		50/262		52/306		53/610	
		% 42 days	+% viable	% 42 days	+% viable	% 42 days	+% viable	% 42 days	+% viable
0. Dry storage at 36°F	—	77	86	53	83	55	85	73	94
1. Wet blotters at 36°F	7	61	71*	67	86	66	82	81	93
" " " "	14	66	72*	79	91	75	86	84	93
" " " "	21	82	86	85	89†	85	91	93	96
" " " "	28	65	67*	87	90†	91*	94	97	98†
2. Soaking in water at 36°F	7	58	62*	72	86	76	87	85	93
" " " " "	14	51	57*	81	86	85	90†	94	97
" " " " "	21	65	65*	88	91†	85	96†	93	96
" " " " "	28	63	64*	89	89†	94	94†	96	96
3. Soaking in water at room temperature	7	68	72*	82	87	69	85	88	93
" " " " "	14	52	53*	81	84	85	90	89	93
" " " " "	21	37	37*	79	82	81	87	87	90*
" " " " "	28	17	17*	81	82	76	86	77	82*

Note: Abbreviations are explained under Table 24.

Excluding lot 49/55 from consideration, all lots showed greatly increased germination at 42 days following some pretreatments. Total germination capacity as indicated by the 42 day germination+viable seeds in Table 28, was not much affected although 21 and 28 days moist prechilling caused a slight increase.

THE EFFECT OF SEED PRETREATMENT ON THE RATE OF GERMINATION OF LODGEPOLE PINE

Table 29

Seed Pretreatment	Period of Treatment (days)	Number of days required for Germination of 90 per cent of Seeds capable of Germination			
		Lot 49/55	Lot 50/262	Lot 52/306	Lot 53/610
0. Dry storage at 36°F	—	45	> 100	> 100	> 100
1. Wet Blotters at 36°F	7	45	90	100	100
" " " "	14	35	40	60	45
" " " "	21	18	26	26	<14
" " " "	28	17	<14	<14	<14
2. Soaking in water at 36°F	7	26	55	60	40
" " " " "	14	42	18	21	16
" " " " "	21	18	<14	<14	<14
" " " " "	28	19	<14	<14	<14
3. Soaking in water at room temperature	7	20	28	65	15
" " " " " "	14	19	18	24	16
" " " " " "	21	18	<14	18	<14
" " " " " "	28	17	<14	42	26

It is interesting to note that with the exception of 49/55, soaking in water at room temperature increased germination, with no sign of seed deterioration even after 28 days soaking, which is in marked contrast to the results obtained with Douglas fir. The figures in Table 29 provide a measure of the effects of the treatments on the *rate* of germination.

With the exception of the shortest period of treatment on wet blotters at 36°F, all treatments increased the rate of germination considerably. Soaking in water at 36°F for 21 days gave the most rapid and consistent germination, while soaking on wet blotters at this temperature was slightly less effective and required the full 28 days pretreatment to produce the maximum effect. Soaking the seed in water at room temperature also greatly increased the rate of germination. soaking for a period of 21 days under these conditions resulted in completion of 90 per cent of germination in 14 to 18 days compared with 45 to 100 days for untreated seed.

Summary and Conclusions

Sitka spruce: Pretreatment by soaking the seed in water or on wet blotters for a period of 21 days at 36°F before germination test gave the maximum increase of germination rate. There was some suggestion that soaking in water for such periods may cause a slight depression of germination capacity, and the wet blotter technique is regarded as the safer treatment. One seed lot of low germination showed only a small increase of germination rate following treatment and in this case germination capacity was depressed by all treatments.

Douglas fir: No treatment had any consistent effect on germination capacity with the exception of soaking in water at room temperature which caused a pronounced depression if continued for periods longer than 7 days. Soaking the seeds on wet blotters at 36°F for 21 days gave the most rapid germination.

Lodgepole pine: Germination capacity was not greatly affected by any pretreatment although prechilling for 21 or 28 days resulted in a slight increase with some seed lots. The effects on speed of germination were great. Seeds soaked in water at 36°F for 21 days increased the rate of germination considerably, and gave results comparable with those obtained after soaking the seeds on wet blotters at the same temperature.

Most of the effects observed in these trials were fairly clear cut; however, further work is required to examine the effects on a wider range of qualities of seeds. In particular an attempt must be made to explain the behaviour of seed such as the old seed of lodgepole pine, and the low quality seed of Douglas fir, which failed to show typical responses to pretreatment in these first trials. In the majority of cases the increase of germination rate following pretreatment was so pronounced that the methods are worthy of serious consideration as standard practice for application to seeds before laboratory germination tests on these species. It can be argued that these pretreatments offer no advantage over normal methods as when the pretreatment period is taken into account the total time required to complete a germination test is no shorter than that for untreated seeds. But the following advantages must also be taken into consideration.

(1) The actual time in the laboratory germinator is reduced from over 42 days to 21 days, and in this time germination is completed so that the percentage of ungerminated viable seeds rarely exceeds 5 per cent.

(2) Rapid and uniform germination facilitates an accurate estimation of germination energy, and also the progress of germination is not upset

by the development of fungi on the seeds, as frequently happens during tests extending over longer periods.

(3) A larger number of tests can be completed with a given germinator space.

The possible value of such pretreatments for obtaining earlier and more uniform germination of seed under nursery conditions has not yet been investigated.

REFERENCES

ALLEN, C. S. (1941)	*For. Chron.*, 17, 99-109. (*For. Abs.*, 5, p. 29.)
BARTON, L. V., and CROCKER, W. (1948)	*Twenty Years of Seed Research at the Boyce Thompson Institute.* Faber and Faber, Lond. (*For. Abs.*, 10-1763.)
CROSSLEY, D. I., and SKOV, L. (1951)	*Silv. Leafl. For. Br. Can.* No. 59, 1951, p. 4 (*For. Abs.*, 13-2056.)
HOLMES, G. D. (1951)	*Rep. For. Res. For. Comm.* London. 1950/51, 1952 (13-5). (*For. Abs.*, 15-1280).
ROHMEDER, E. (1939)	*Forst. Cbl.* 61 (393-406). (*For. Abs.*, 1, p. 161.)
ROHMEDER, E. (1951)	*Beiträge für Keimungsphysiologie der Forstpflanzen*, Munchen.
RUDOLF, P. O. (1950)	*J. For.* 48, p. 31.
STEVEN, H. M. (1928)	*For. Comm. Bull.*, No. 11.
TOUMEY, J. W., and DURLAND, W. D. (1923)	*J. For.*, 21, p. 369.

EXPERIMENTS ON APPLYING VARIOUS FORMS OF NITROGEN TO SITKA SPRUCE SEEDBEDS IN SCOTLAND

By R. FAULKNER, *Assistant Silviculturist*

THE object of these investigations was to find an effective and cheap medium for the application of nitrogen to conifer seedbeds in forest nurseries. It has long been recognised that the application of some form of nitrogenous manure, either directly to the seedbeds, to a greencrop in the previous season, or in both these ways, is essential if satisfactory crops of coniferous seedlings are to be raised. As yet, however, there is no standard practice of nitrogen manuring or greencropping, and the current position is reviewed below.

Previous experimental work had suggested that organic nitrogenous fertilisers which release available nitrogen gradually are more suitable for coniferous seedbeds than highly soluble inorganic fertilisers such as ammonium sulphate and "Nitrochalk" which release available nitrogen fairly rapidly. For this reason the substances selected for test were flash (a urea formaldehyde plastic), formalised casein, hoof and casein, hoof and horn meal, fish guano, and vegetable meal, while "Nitrochalk", a quick-acting inorganic fertiliser, was included to give comparisons. It is important that any fertiliser which is to be used on a large scale should be reasonably cheap, not simply in terms of cost per ton of bulk material, but in terms of useful nitrogen content.

CURRENT PRACTICES IN THE NITROGEN MANURING OF CONIFER SEEDBEDS IN THE SCOTTISH NURSERIES OF THE FORESTRY COMMISSION

Nurseries on Agricultural Types of Land

In the majority of the older Forestry Commission nurseries in Scotland, which are sited on agricultural types of land, raising a greencrop on ground to be followed by seedbeds is practised. The greencrop, quite apart from acting as an organic additive to the soil, when ploughed under, also helps to control weeds and provides a small potential of nitrogen which is gradually liberated during the katabolic activities of the micro-biological agencies in the soil. The small amount of nitrogen liberated during the breakdown of greencrop residues in the second year appears however to be generally insufficient to satisfy the full demands of a crop of tree seedlings, and fertiliser nitrogen is frequently applied to the seedbeds as basal or top dressings, or combinations of the two.

It has proved impossible to quote an average prescription for current nitrogen manuring regime in Scottish nursery seedbeds, because both the actual fertilisers and amounts applied vary from one nursery to another, while changes in manuring practice frequently take place. But a review of manuring prescriptions for ten nurseries in 1952, enabled the following general conclusions to be made:

(*a*) Greencrops usually receive a basal dressing of ammonium sulphate, and quite often a top dressing of ammonium sulphate totalling together 2 to 3 cwt. per acre.

(*b*) Basal dressings of nitrogenous fertilisers are not given to seedbeds at the majority of nurseries.

(*c*) Top dressings of nitrogenous fertilisers are given to first-year seedbeds at several nurseries.

(*d*) The amounts of nitrogenous fertilisers applied to seedbeds vary considerably, 2 cwt. of "Nitrochalk" per acre being an average figure.

(*e*) Ammonium sulphate is the most popular nitrogenous fertiliser for greencrops, and "Nitrochalk" is the most popular for seedbeds.

Note: Ammonium sulphate is used in many conifer nurseries to supply nitrogen and also to provide a gradual means of reducing the soil pH values to between 5.4 and 5.6, where these exceed the latter value. Basal dressings of phosphate and potash are invariably applied to greencrops and often to seedbeds also.

Woodland and Heathland Nurseries

Greencropping is not practised in Scottish woodland or heathland nurseries. Basal dressings of phosphate and potash are always given and organic matter is added to the soil in the form of raw hopwaste, at annual or biennial application rates of 16 to 20 tons per acre. These organic matters contain a small amount of nitrogen (2%-5% total nitrogen) which quite often is supplemented by "Nitro-chalk" applications applied basally or as top dressings to seedbeds at rates averaging 2½ cwt. per acre.

EXPERIMENTS TO COMPARE VARIOUS FORMS OF NITROGENOUS MANURES

The object of the experiments was defined thus:

To compare the effect of various organic forms of nitrogen and dressings of "Nitrochalk", in two or three applications, on the germination of seed and the survival and growth of conifer seedlings.

Sitka spruce was used throughout as the indicator species, since previous experience in nursery experimental work has proved it to be more sensitive to manurial dressings than other commonly raised conifers. Each year for three years, 1949-1951, the experiment was repeated at six widely scattered nurseries in Scotland, namely, Newton, Morayshire; Inchnacardoch, Inverness-shire; Tulliallan, Fife; Benmore, Argyll; Wauchope, Roxburghshire; and Fleet, Kirkcudbrightshire.

The experiment included five different organic forms of nitrogenous fertilisers mixed into the soil to a depth of three to four inches before sowing in March or April, plus plots with no nitrogen. These were combined factorially with the inorganic nitrogenous fertiliser "Nitrochalk", which was applied by one of two different systems, together again with plots with no nitrogen. Therefore there were eighteen combination treatments; these were repeated in four blocks.

In one system the "Nitrochalk" was divided into two equal top dressings, one being applied in early July and one towards the end of July. The "Nitrochalk" application took place preferably when a rain shower was imminent. If the application took place during a dry period the seedlings were lightly brushed to ensure that the "Nitrochalk" fell to the ground, thus avoiding any chance of the fertiliser burning the seedling foliage.

In the second system the "Nitrochalk" dressing was divided into thirds, one third being applied basally, at the same time as the organic fertilisers, and the other two thirds separately at the same times of application as the two top dressings used in the first system.

In both systems the total amount of nitrogen applied was equivalent to 0.25 oz. N per square yard (=0.67 cwt. of N per acre), whereas the calculated amount of nitrogen in all the organic nitrogen treatments was 0.50 oz. N per square yard (=1.3 cwt. of N per acre). The smaller dosage of nitrogen for inorganic nitrogen treatments was prescribed on account of the quicker rate of liberation of nitrogen when compared with materials containing organic forms of nitrogen.

Basal dressings of nitrogen organic manures were applied and cultivated into the soil to a depth of three to four inches, along with superphosphate and sulphate of potash, at least seven days before sowing. The rates of applying phosphate and potash were sufficient to ensure that lack of these elements would not limit growth.

Experimental Materials

The organic materials were:

Flash. A urea-formaldehyde resin containing hoof meal as a filler, produced in the plastic industry when articles are being moulded by compression. When two moulds are placed together the plastic which is squeezed out between them is referred to as "flash" and forms a waste product. The "flash" used in the experiments had a total nitrogen content of approximately 23 per cent. This "flash" showed a percentage mineralization of nitrogen of 7.2 per cent, after incubation for 6 months in mixture with a soil of pH 7.3, at laboratory temperatures, by the method described by Winsor and Long 1951 (1).

Formalised casein. This material is also a waste product of the plastic industry and is manufactured by soaking casein plastic in formalin. Waste material is usually obtained as "offcuts", which are ground to a suitable size for mixing into the soil. It has a nitrogen content of around 12 per cent.

Hoof and casein. This product was substituted for formalised casein in some of the 1950 experiments. It was a mixture of hoof meal and casein in 1:1 ratio by weight and had a nitrogen content of 13.6 per cent.

Hoof and horn meal. Material derived from the ground hooves and horns of animals. The highest grade contains approximately 14 per cent of nitrogen.

Fish guano. This material consists of fish offal which has been dried and ground to a powder form. It contains approximately 6 per cent nitrogen.

Vegetable meal. A by-product, mainly cocoa residues, from the synthetic drinks industry. The nitrogen content is low and around 3 per cent.

"Nitrochalk". An inorganic nitrogen-containing material produced by mixing one part by volume of fine chalk with two parts of a hot saturated solution of ammonium nitrate; the mixture is sprayed into a tower and in falling and cooling produces a granular material. The nitrogen content is approximately 15 per cent.

In laying down the experiments the basal nitrogen manurial treatments were applied over a 3 ft. 6 inch by 3 ft. 6 inch area of seedbed and where necessary cultivated into the top three inches of soil. At the same time a standard basal dressing of phosphate (P) and potash (K) were cultivated into the soil to the same depth. The standard dressing used was P, at 0.4 oz. P_2O_5 per square yard, as superphosphate, and K, at 0.3 oz. K_2O per square yard, as sulphate of potash. A six inch buffer of untreated soil separated each treatment. At least one week after applying the manures, 5.3 grams of Sitka spruce seed was broadcast sown over the centre square yard of the manured plot (i.e. at a rate equivalent to the Forestry Commission standard rate of 85 square yards per pound of seed) and the whole plot was then covered with a $\frac{3}{16}$ inch cover of a suitable grade of grit.

The Effect of Nitrogenous Manures on the Germination of Seed

In 1949, the first year of the experiment, no record was kept of the effect of the nitrogen treatments on the speed of germination. It was visibly obvious, however, that there were marked differences between treatments, and these indications prompted the inclusion of germination assessments in the 1950 and 1951 experiments.

The assessments were based on a hundred per cent count of all seedlings at the time of the first assessment (i.e. when the slowest plot to germinate in each experiment showed a production of approximately twelve seedlings per square yard). Three subsequent counts were made on approximately the 12th, 24th and 36th day after the first assessment. The three last counts were made on a 6 per cent sample of the population of seedlings.

The results indicated quite clearly that vegetable meal and fish guano had a very pronounced retarding effect upon the rate of germination, of the order of a

20 to 50 per cent reduction in numbers during the first two to three weeks. Other organic forms of nitrogen, and in particular hoof meal, all produced a very slight retarding effect, but this reduction in speed of germination was seldom significant at the five per cent level.

The depressing effect of vegetable meal and fish guano upon the rate of germination may be attributed to a variety of reasons, one being the texture of the soil after applying the manures. Both are light bulky manures with low nitrogen contents, thus a comparatively large volume of material had to be applied in order to add the requisite 0.5 oz. of nitrogen per square yard. Accordingly the soil texture was lightened and subsequent consolidation was in all probability considerably less effective than on other plots where the materials were of a denser nature. Lack of consolidation is known to reduce the amount and rate of germination. Another possible reason is that in the process of breakdown of these bulky manures the speed of nitrogen liberation may have been more rapid than with the other materials, and if so the surfeit of nitrogen in the upper layers of the soil may have proved harmful during the time of germination.

EXPERIMENTAL RESULTS AT THE END OF THE GROWING SEASONS

In a factorial experiment of the type used, the main effects of the organic nitrogen fertilisers can be compared amongst themselves, the "main effect" of each fertiliser being the amount by which it increased, or decreased, the height or number of seedlings, in comparison with the average result for the remaining plots which received no nitrogen. Similarly the main effects of the inorganic "Nitrochalk" fertiliser applications can be compared with each other, or compared with the average result for all the plots not receiving any nitrogen.

Many of the plots received a combination of both organic and inorganic nitrogen fertiliser, and it was expected that under such conditions interaction effects would become apparent. Thus the combination of a dressing of, say, hoof meal, containing 0.5 oz. N per square yard, with a "Nitrochalk" dressing of 0.25 oz. of N per square yard applied later in the season might well have proved to be an overdose. This was not so, in fact a detrimental effect was produced only once in eighteen experiments. This observation is of importance because it indicates that even relatively heavy doses of nitrogen can be given with safety.

In late September each year, when seedling shoot growth had ceased, the experiments were assessed for mean heights and numbers of plants. The assessment was based on a 22.2 per cent count of all seedlings in each square yard plot using four systematically placed 2 inch by 36 inch grids. An overall summary of results from these assessments is given in Tables 30 and 31. It should be noted that there were several height and number interactions between years, nurseries, and mean heights treatments. Details of these have been omitted from this report.

Mean Heights

Comparisons between Individual Organic Manures. In the majority of nurseries in 1949, 1950 and 1951, formalised casein produced the tallest plants, and in 1950 when hoof casein was substituted at three of the nurseries the same effect was obtained. Flash was the second best treatment, although on occasions hoof meal produced seedlings equally tall or even taller. Hoof meal, when compared

COMPARISONS OF MEAN HEIGHTS OF ONE-YEAR SITKA SPRUCE RAISED ON PLOTS TREATED WITH ORGANIC AND INORGANIC MANURES

Table 30 Data based on averages for six nurseries and three years. (18 experiments)

Treatment	Mean Height in inches
Flash (F)	1.40
Formalised casein and hoof casein (C)	1.49
Hoof and horn meal (H)	1.31
Fish guano (G)	1.27
Vegetable meal (V)	1.11
Mean of all plots without organic nitrogen treatments	1.29
Standard Error	±0.05
Differences necessary for significance 5%	0.15
Differences necessary for significance 1%	0.20
Nitrochalk in two equal top dressings (N_2)	1.30
Nitrochalk as one third basal with two separate ⅓ top dressings (N_3)	1.33
Mean of all plots without inorganic nitrogen treatments	1.28
Standard Error	±0.01
Differences necessary for significance 5%	0.04
Differences necessary for significance 1%	0.06

with the two remaining treatments, fish guano and vegetable meal, generally produced the taller plants, but at Benmore in particular it was erratic over the years and, in some instances, produced smaller seedlings. Vegetable meal in general produced smaller seedlings than fish guano. Both of these treatments usually produced very small seedlings indeed. The marked retarding effect on the rate of germination which these materials produced reduced the effective length of the growing season for the resulting crop, and this may in part account for the small height growth recorded.

Comparison between the Two Systems of Applying "Nitrochalk". Almost without exception differences were negligible between applying "Nitrochalk" as two top dressings in July, or as one third basally with the remaining two separate thirds applied in July. Overall it appeared that applying "Nitrochalk" in thirds was very slightly better for promoting height growth than applying the material in two July top dressings.

Fig. 5 opposite gives an appreciation by years, and in all years, of the mean heights of seedlings on seedbeds treated with individual organic or inorganic nitrogen treatments *alone* (not in factorial combination with other manures).

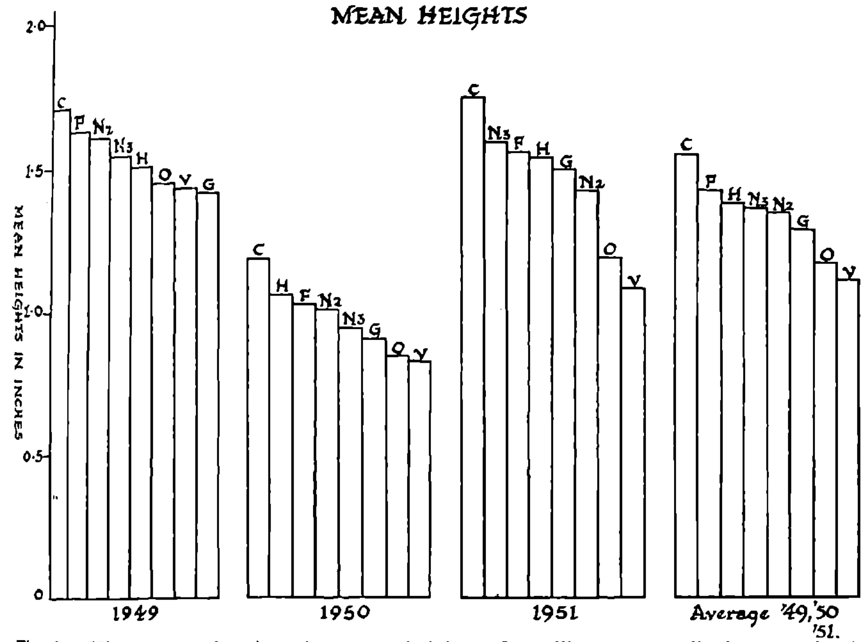


Fig. 5. Histograms showing the mean heights of seedlings on seedbeds treated with organic and inorganic nitrogen treatments alone. Data are presented by years averaged over six nurseries, and also averaged over the three years at six nurseries.

C— Formalised casein	at rates equivalent to 0.5 ozs N per sq. yd.
F— Flash	" " " " " " " " " " "
H— Hoof and horn	" " " " " " " " " " "
G— Fish guano	" " " " " " " " " " "
V— Vegetable meal	" " " " " " " " " " "
N_3— "Nitrochalk"	(⅓ basal with two separate thirds in July) equivalent to 0.25 ozs. N per sq. yd.
N_2— "Nitrochalk"	(in two July top dressings) equivalent to 0.25 ozs. per sq. yd.
O— Control	(No nitrogen).

Total Numbers

COMPARISONS OF NUMBERS PER SQUARE FOOT OF SITKA SPRUCE RAISED ON PLOTS TREATED WITH ORGANIC AND INORGANIC MANURES

Table 31 Data based on averages for six nurseries and three years. (18 experiments)

Treatment	Total Numbers per Square Foot
Flash (F)	87
Formalised casein and hoof casein (C)	81
Hoof and horn meal (H)	78
Fish guano (G)	64
Vegetable meal (V)	64
Mean of all plots without organic nitrogen treatments	90
Standard Error	± 2
Differences necessary for significance 5%	6
Differences necessary for significance 1%	8
Nitrochalk in two equal top dressings (N_2)	76
Nitrochalk as one third basal with two separate ⅓ top dressings (N_3)	78
Mean of all plots without inorganic nitrogen treatments	78
Standard Error	± 1
Differences necessary for significance 5%	4
Differences necessary for significance 1%	5

Comparisons between Organic Manures. In all cases there is a tendency for most organic nitrogen fertilisers to slightly reduce the numbers of seedlings. This effect was least marked with flash, but was true in practically all the experiments. Formalised casein, and hoof plus casein, hoof and horn meal, fish guano, and vegetable meal, all had a progressive reducing effect upon the number of seedlings, and this was so serious in the case of fish guano and vegetable meal that it precludes their use as seedbed manures for conifers.

Comparisons between the Two Systems of Applying Nitrochalk. Only on two occasions were there any significant differences in total numbers between the two systems of applying "Nitrochalk". On this account both the systems can be regarded as equally safe for applying the material to conifer seedbeds.

Fig. 6 below gives an appreciation of the numbers of seedlings on seedbeds treated with individual organic and inorganic nitrogen materials *alone* (not in factorial combination with other manures).

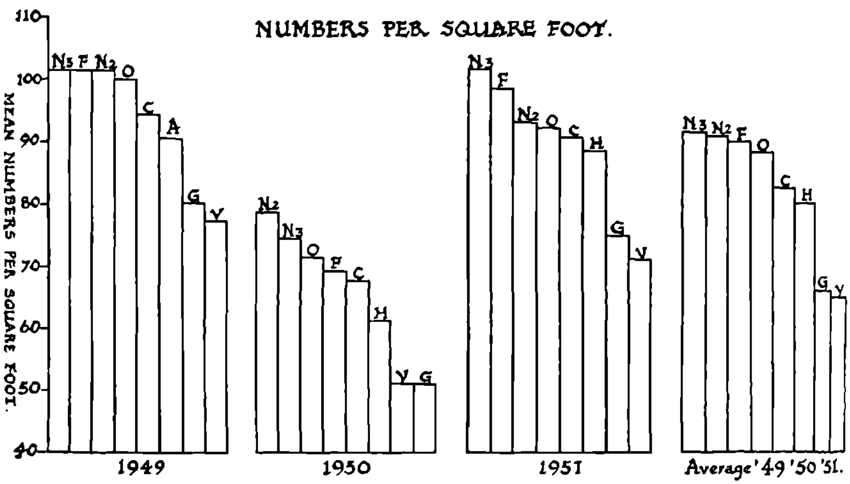


Fig. 6. Histograms showing the numbers of seedlings per square foot on seedbeds treated with individual organic and inorganic forms of nitrogen. Data are presented by years averaged over six nurseries, and also on the average over all three years at six nurseries.

C— Formalised casein	at rates equivalent to 0.5 ozs. N per sq. yd.
F— Flash	,, ,, ,, ,, ,, ,, ,, ,, ,, ,,
H— Hoof and horn	,, ,, ,, ,, ,, ,, ,, ,, ,, ,,
G— Fish guano	,, ,, ,, ,, ,, ,, ,, ,, ,, ,,
V— Vegetable meal	,, ,, ,, ,, ,, ,, ,, ,, ,, ,,
N_3— "Nitrochalk"	(⅓ basal with two separate thirds in July) equivalent to 0.25 ozs. N per sq. yd.
N_2— "Nitrochalk"	(in two July top dressings) equivalent to 0.25 ozs. N per sq. yd.
O— Control	(No nitrogen).

OVERALL COMPARISONS BETWEEN FLASH, FORMALISED CASEIN, HOOF AND HORN MEAL, AND NITROCHALK

The figures given in Tables 30 and 31 are at first sight a little misleading when comparisons are made between any of the organic nitrogen treatments and the "Nitrochalk" treatments. This is because the experiment is factorial in design and the figure presented for, say, flash is an average figure for plots treated with flash alone, and flash in combination with the two systems of applying "Nitrochalk". In the case of the figure for either of the two "Nitrochalk" systems, it was obtained by averaging plots treated with one of the "Nitrochalk" systems alone and in combination with each of the organic nitrogen treatments. Unfortunately, fish guano and vegetable meal had serious reducing effects on numbers of seedlings and as a result this lowered the average figure presented for "Nitrochalk" which consequently does not compare favourably with, say, flash.

On account of this, Table 32 below has been drawn up to compare plots in the experiments which were treated with the three most successful organic nitrogen treatments alone (flash, formalised casein and hoof and horn) with plots which received "Nitrochalk" alone. Since there were only negligible differences between the two systems of applying "Nitrochalk" an average figure for the two has been used.

MEAN HEIGHTS AND NUMBERS OF SEEDLINGS RAISED ON SOILS TREATED WITH FLASH, FORMALISED CASEIN, HOOF AND HORN MEAL AND "NITROCHALK" ONLY

Table 32 (Averages for six nurseries)

Manure	Mean Heights in inches				Numbers per square foot			
	1949	1950	1951	Average of 72 plots	1949	1950	1951	Average of 72 plots
No nitrogen	1.40	0.84	1.16	1.13	100	73	92	88
Flash	1.60	0.99	1.59	1.39	102	71	97	90
Formalised Casein*	1.67	1.15	1.71	1.51	94	68	90	84
Hoof and Horn Meal	1.47	1.03	1.47	1.32	88	62	87	79
"Nitrochalk"	1.52	0.97	1.40	1.30	103	76	98	92

*Hoof and Casein substituted at three nurseries in 1950.

From Table 32 it will be seen that formalised casein was the outstanding treatment as regards height production, with flash consistently second, hoof meal third, and "Nitrochalk" fourth. There was very little difference between hoof and horn meal and "Nitrochalk", but from a complete tabulation by years and nurseries (not presented) it is observed that "Nitrochalk" gave results which were far more consistent than hoof and horn meal.

The general marked reduction in seedling heights in 1950 was probably due to the very poor growing season experienced in most parts of Scotland during this year. The months of May and June were very dry, and in August and September rainfall was high and hours of sunshine low. 1949 and 1951 were both good growing seasons, being characterised by warm sunny springs, and mild weather in August and September.

Numbers of seedlings were least affected by "Nitrochalk", and flash; formalised casein had an appreciable reducing effect, and hoof and horn meal had a more serious effect. In 1950 the yield of seedlings was markedly lower than in 1949 and 1951, a fact attributed to the long dry spring coupled with the fact that the germination percentage of the seed was lower than in 1949 and 1951.

DISCUSSION AND CONCLUSIONS

This series of experiments, designed to throw some light on the problem of nitrogen manuring of coniferous trees in forest nurseries, has confirmed to some extent previous experiences of workers in similar fields of research in agriculture.

The speed of nitrogen liberation in a soil varies tremendously according to the soil type, temperature, water content and a host of other minor uncontrollable factors. On the other hand, the condition and size of the plant plays a considerable part in the degree of utilization of the nitrogen available at any one time.

The organic nitrogen-containing materials chosen for the experiments offered a widely contrasting range of waste products which are relatively cheap and available, or likely to be available, in quantity in the future. The waste plastics were selected chiefly because they were regarded as slow acting and therefore likely to yield a steady and fairly constant supply of nitrogen in the soil throughout the growing season. No real account was taken into consideration of the particle size of the ground plastics, although it was realised that the particle size plays an important part in the speed of nitrogen liberation. Additional points in favour of plastics are the fairly uniform nitrogen content, cleanliness, ease of handling and storage, lack of offensive smell, and concentrated bulk.

Final results show that the plastics are the most promising of all the organic materials used. Flash has less effect on total numbers than formalised casein, but against this the formalised casein produced larger plants. Thus there is little to choose between the two when applying the materials to spruce seedbeds; both can be strongly recommended as suitable fertilisers.

Hoof and horn meal is very much akin in properties to the plastics, although the nitrogen content is subject to a greater amount of variation. On account of this it is usually sold in various grades depending on the nitrogen content. The product until recent years was widely used in many Forestry Commission nurseries but "Nitrochalk" has largely replaced it. Its general reducing effect on total numbers, which at Newton in 1950 amounted to as much as 30 per square foot, or approximately 22,000 per pound of Sitka spruce seed, has probably not been fully realised hitherto. Its cost per unit of nitrogen is twice that of "Nitrochalk".

The remaining organic products, vegetable meal and fish guano, offered an apparently cheap, but as it proved in the long run, an unsuitable nitrogen manure. They would be fairly readily available in large quantities if demands were made, but because of their drastic effect in reducing seedling yields, their large bulk, and offensive smelling properties, they do not warrant further consideration.

"Nitrochalk", the inorganic nitrogen-containing material, has an initial advantage of being one of the cheapest manures per unit of nitrogen. It has given satisfactory results under Scottish field conditions when applied in two top dressings in July totalling approximately 4¼ cwt. per net acre of seedbed, and this experience was confirmed by these experiments. Although the chemical is relatively quick acting and therefore rapidly dissipates in the soil, it does produce satisfactory growth of seedlings, more so than on first appearances, when it is recalled that "Nitrochalk" dressings were calculated to yield 0.25 oz. N per square yard, or half the calculated amount of nitrogen contained in the more slowly acting organic fertilisers.

"Nitrochalk" has one disadvantage as a material for wide-scale application and that is its hygroscopic property. This makes long periods of storage in buildings subject to dampness difficult, and necessitates the manure being purchased and used as quickly as possible.

It must be stressed here that all the experimental results have been obtained using Sitka spruce as indicator species. Other commonly used conifers such as pines, Norway spruce and Douglas fir are, judging from previous manurial experiments, likely to be less sensitive to the form in which nitrogen is applied. From this it can be taken that whatever material is suitable for Sitka spruce will in all probability be highly suitable for other species.

It was apparent that the cost per unit of nitrogen supplied varied widely for the various fertilisers. Details are given in Table 33 below, from which it will be seen that the unit cost, expressed as the price per ton over the percentage nitrogen content, was lowest at 17s. 6d. for flash, and highest at £8 3s. 0d. for vegetable meal.

COSTS PER UNIT OF NITROGEN CONTAINED IN THE MANURES USED IN THE EXPERIMENTS

Table 33 Costs are calculated from 1953 figures

Manure	Percentage Nitrogen	Cost per cwt. of manure	Cost per unit of nitrogen = Price per ton / % nitrogen
Nitrochalk	15.5%	22/9	£1 9 4
Flash	22.8%	20/-	17 6
Formalised Casein	11.8%	25/-	£2 2 3
Hoof and horn meal (top grade)....	12.7%	56/-	£4 8 2
Fish guano	6.5%	40/-	£6 3 0
Vegetable meal	2.3%	18/9	£8 3 0

Summing up, the evidence indicates that of the materials tried, flash, formalised casein, or "Nitrochalk" should be preferred as the most suitable and economical for conifer seedbeds. Formalised casein and flash are still in relatively short supply and until they become more freely available, July top dressings of "Nitrochalk" in established nurseries are recommended.

REFERENCE

(1) Winsor, J. W., and Long, M. I. E. Chemical Investigations No. 4, I. Properties of some Urea-Formaldehyde Materials in Relation to their possible use as nitrogenous fertilisers. 1951 *Annual Report Cheshunt Experimental Station*, pp. 56-67.

RELATIONSHIP BETWEEN THE PERCENTAGE OF USABLE CONIFER SEEDLINGS AND THE MEAN HEIGHT OF SEEDLINGS AS ASSESSED AT STOCKTAKING

By J. N. R. JEFFERS, *Mensuration Section*

In Forestry Commission nursery practice, a "usable" seedling is defined as a seedling which has a height of more than one and a half inches, excluding seedlings with defective or forked leading shoots. This definition is arbitrary, but it has been found to give a good indication of the numbers of seedlings which are sufficiently large to be transplanted; and the percentage of usable seedlings in any given stock of seedlings is an important factor to be considered in nursery management. If at the end of one year in the seedbed, the percentage of usable seedlings is high, it is probably more economical to line out the seedlings than to leave them in the seedbed for a second year. If, on the other hand, the percentage of usable seedlings is low, the seedlings must be left in the seedbed for a further year, with a consequent increase in the cost of raising them.

Nursery experiments carried out by the Forestry Commission Research Branch are usually assessed in terms of the total numbers of seedlings produced, and the mean height of those seedlings. It is relatively easy to determine the number of usable seedlings from these assessments for any particular experiment. But a knowledge of the general relationship, which must exist between the percentage of the total number of seedlings which are "usable" and the mean height of the seedlings, is of greater value in making clear the effect on the "usability" of the seedlings, of increasing or decreasing their mean heights by a given treatment.

To provide data on this relationship, the numbers and heights of one year seedlings were assessed in several Scottish nurseries at the end of the growing season in 1951. The assessment unit was the area enclosed by a standard two inches by thirty-six inches wire grid, i.e. 72 square inches. Table 34 gives the numbers of grids assessed, the numbers of seedlings measured, and the range of mean heights for each species, and also the nurseries in which the seedlings were assessed.

ASSESSMENT OF ONE-YEAR CONIFER SEEDLINGS FOR USABILITY

Table 34

Species	Nursery	No. of grids assessed	Total No. of seedlings	No. of usable seedlings	Range of mean heights (inches)
Scots pine	Devilla	100	2,146	1,022	1.07–2.60
	Edinburgh Botanic Gdn.	12	389	165	1.17–2.31
	Tulliallan	6	178	2	0.68–1.10
Japanese larch	Devilla	100	4,708	2,460	0.77–4.00
	Fleet	140	2,777	1,558	0.90–2.72
	Edinburgh Botanic Gdn.	20	653	438	1.17–5.79
	Tulliallan	40	925	212	0.75–1.99
Douglas fir	Devilla	100	1,498	1,009	0.92–3.81
	Fleet	140	3,927	2,320	1.15–2.83
	Edinburgh Botanic Gdn.	20	472	127	0.97–1.96
	Tulliallan	40	1,445	448	0.87–2.12
Norway spruce	Fleet	280	10,399	6,157	0.87–2.66
	Tulliallan	3	134	0	0.65–0.86
Sitka spruce	Devilla	100	5,278	3,752	1.32–3.18
	Fleet	120	4,179	2,145	0.88–3.43
	Edinburgh Botanic Gdn.	60	2,514	963	0.91–1.73
	Tulliallan	20	962	89	0.52–1.51

The total numbers of seedlings and the numbers of usable seedlings for each species were grouped by the mean heights for the lots assessed by using the grids. The intervals of the heights used were 1.00-1.09 inches, 1.10-1.19 inches, 1.20-1.29 inches etc., so that the mid-values of the height classes were approximately 1.05 inches, 1.15 inches, 1.25 inches, etc. For each height class, the percentage of usable seedlings was calculated.

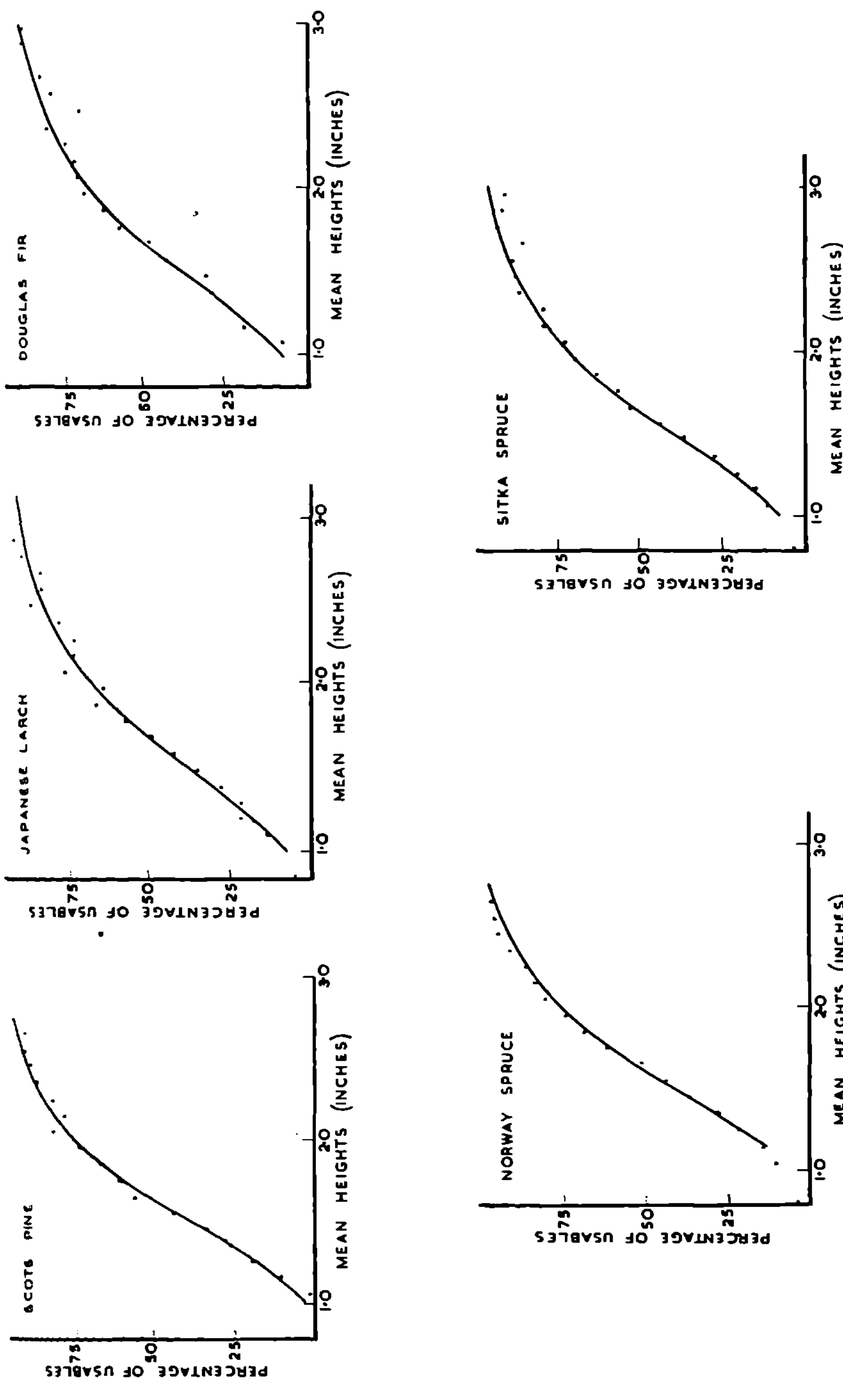


Fig. 7. Comparison of mean height of various lots of first-year seedlings, as assessed at stocktaking and the percentage classed as usable, for five coniferous species.

The average percentages of usable seedlings are plotted over the mid-values of the height classes in Figure 7. The individual points from all nurseries fall approximately along a smooth curve, and, for all five species, this takes the form of a skewed sigmoid curve.

Finney (1947) has shown that such curves can be transformed into straight lines by the use of the probit transformation, and that, by the use of appropriate regression methods, estimates of the true relationship can be obtained. These methods were applied to the data from the seedling assessments, and the resulting relationships are shown as the continuous curves in Figure 7. Table 35 gives these relationships in tabular form for each species.

RELATIONSHIP BETWEEN MEAN HEIGHT OF VARIOUS LOTS OF SEEDLINGS, AS ASSESSED AT STOCKTAKING, AND PERCENTAGE OF USABLE ONE-YEAR CONIFER SEEDLINGS IN EACH LOT

Table 35

Mean height of lot in inches	Percentage of usable seedlings:—				
	Scots pine	Jap. larch	Douglas fir	Norway spruce	Sitka spruce
1.0	4	9	9	6	8
1.1	8	14	13	10	13
1.2	14	20	19	16	19
1.3	21	26	25	24	25
1.4	29	32	32	32	33
1.5	37	39	39	41	40
1.6	46	46	46	50	47
1.7	55	52	52	57	54
1.8	62	58	58	65	60
1.9	70	63	63	71	66
2.0	75	68	68	77	71
2.1	81	73	73	81	76
2.2	85	76	77	85	80
2.3	88	80	80	88	83
2.4	91	83	83	91	86
2.5	93	85	86	93	88
2.6	95	87	88	95	90
2.7	96	89	90	96	92
2.8	97	91	91	97	94
2.9	98	92	93	98	95

From this table it is possible to estimate the average percentage of seedlings which would be "usable" i.e. over one and a half inches in height, for any given mean height between 1.0 inches and 2.9 inches. The conclusions suggested by the table are:—

(*a*) For beds of seedlings with a mean height of less than 1.0 inches, less than ten per cent. of the seedlings of any of the species tested are usable.

(*b*) For beds of seedlings with a mean height of 3.0 inches or over, more than ninety per cent of the seedlings of any of the species tested are usable.

(*c*) For all the species tested, beds of seedlings with mean heights between 1.6 inches and 1.7 inches have about fifty per cent of usable seedlings.

(*d*) Japanese larch and Douglas fir have the same percentage of usable seedlings for mean heights between 1.0 and 3.0 inches.

(*e*) Sitka spruce has about the same percentage of usable seedlings as Japanese larch and Douglas fir, for mean heights between 1.0 inches and 1.5 inches, but for mean heights greater than 1.5 inches, Sitka spruce has higher percentages of usable seedlings than these two species.

(*f*) The percentages of usable seedlings are very similar for Scots pine and Norway spruce, for mean heights greater than 2.0 inches, but for mean heights of less than 2.0 inches, Scots pine has lower percentages of usables.

It should be stressed that Table 35 should only be used to estimate the percentages of usable seedlings for batches of seedlings with a given mean height. It should not be used in the opposite way, i.e. to estimate the mean heights of the seedlings for batches of seedlings with given percentages of usable seedlings.

The relationship between percentage of usable seedlings and mean height of all seedlings has been calculated from data from Scottish nurseries in one year. Although it is possible that this relationship may change from year to year, and from one part of Britain to another, the percentages in Table 35 have been found to give reasonable estimates in other years and localities.

Other Standards of Usability

Table 36 only gives the percentage of usable seedlings when the lower limit for the usable seedling is one and a half inches, and, although this limit is generally accepted, it may be desirable to calculate the percentage of seedlings with heights greater than some other limit. To enable this to be done, the standard deviations of the heights of the seedlings in the sample defined by each grid were calculated and plotted over the mean heights for the samples. It was found that the regression of the standard deviations on the mean heights was linear, and the regression equations were calculated for each species. Table 36 gives the standard deviations of the heights for seedlings of given mean heights for the five species, calculated from the regression equations.

STANDARD DEVIATIONS OF HEIGHTS OF ONE-YEAR CONIFER SEEDLINGS, FOR VARIOUS MEAN HEIGHTS

Table 36

Mean height (inches)	Standard deviation of heights in inches:—				
	Scots pine	Jap. larch	Douglas fir	Norway spruce	Sitka spruce
1.0	0.22	0.43	0.38	0.29	0.36
1.5	0.42	0.57	0.56	0.44	0.52
2.0	0.61	0.72	0.75	0.58	0.69
2.5	0.81	0.87	0.94	0.73	0.86
2.9	0.97	0.99	1.09	0.84	0.99

These standard deviations, together with a table of the Normal frequency distribution, enable the percentage of seedlings with heights greater than any given limit to be estimated for any given mean height. The difference between the limit of the usable seedlings and the mean height is divided by the appropriate standard deviation to give a standard difference. The percentage of usable seedlings then corresponds to the proportion cut off from one "tail" of the Normal distribution by the resulting standard difference.

Thus, to find, for a batch of Scots pine seedlings with a mean height of 2.9 inches, the percentage of seedlings with a height of more than 2.0 inches, the standard difference is found as follows:

$$\frac{2.9-2.0}{0.97} = \frac{0.9}{0.97} = 0.93$$

From a table of the Normal frequency distribution (e.g., Snedecor, 1946, p. 100) the proportion of seedlings over 2.0 inches is given as 0.5000+0.3340, which is approximately 83 per cent.

REFERENCES

D. J. Finney, 1947 *Probit Analysis.* Cambridge University Press.

G. Snedecor, 1946 *Statistical Methods, applied to Experiments in Agriculture and Biology.* Iowa State College Press.

TRIALS OF SPECIES IN THETFORD CHASE FOREST

By R. F. WOOD, *Silviculturist, South,* and M. NIMMO, *Assistant Silviculturist.*

The Breckland district of East Anglia, of which Thetford Chase Forest now occupies a considerable part, is a region which provides a somewhat special environment for tree growth. It has attracted a considerable literature, and the ecological studies of Watt (1936) give a very full description of the locality factors.

The environment has proved suited for only a restricted number of tree species in large-scale planting. In this article, the behaviour of a number of species in the principal trials will be used to illustrate these limitations, and where possible distinction will be made between temporary and more permanent limiting factors to tree growth.

Climate and Site

Breckland lies almost centrally in the East Anglian "bulge", a region with a markedly low rainfall. The thirty-year average to 1935 at Thetford is 23.8 in. Rainfall in the east of England is rather more favourably distributed than elsewhere in Britain, some 48.9 per cent of annual rainfall occurring in the six months April to September. (The comparative figure for the west of Scotland is 42.2 per cent (Bilham 1938).) It is also relatively reliable in annual occurrence, the mean percentage deviation from the long term normal is about 11 to 12 per cent, as compared with the extreme value of 16 per cent for the region of the lower Severn valley (Glasspoole, 1930).

Penman (1950) estimates the mean evapo-transpiration for the region at 17 in, some 90 per cent of which occurs in the summer half of the year. Hence, on average, "need" exceeds rainfall in the period April to September by about 4 inches. Penman's map of evaporation values suggests that climatically drier conditions may occur in England over much of Essex and the lower Thames valley and at certain points on the south coast; wherever in fact the evaporation exceeds 20 inches and rainfall does not reach 30 inches. While it is safe to say

Photo 1. Christie : Douglas Fir Sample Plots at Tortworth, Gloucestershire : General view of Ironmill Grove. Plot E20 is on the left and the better Plot E19 on the right.

Photo 2. Christie : Douglas Fir Sample Plots : Plot E20 at Tortworth.

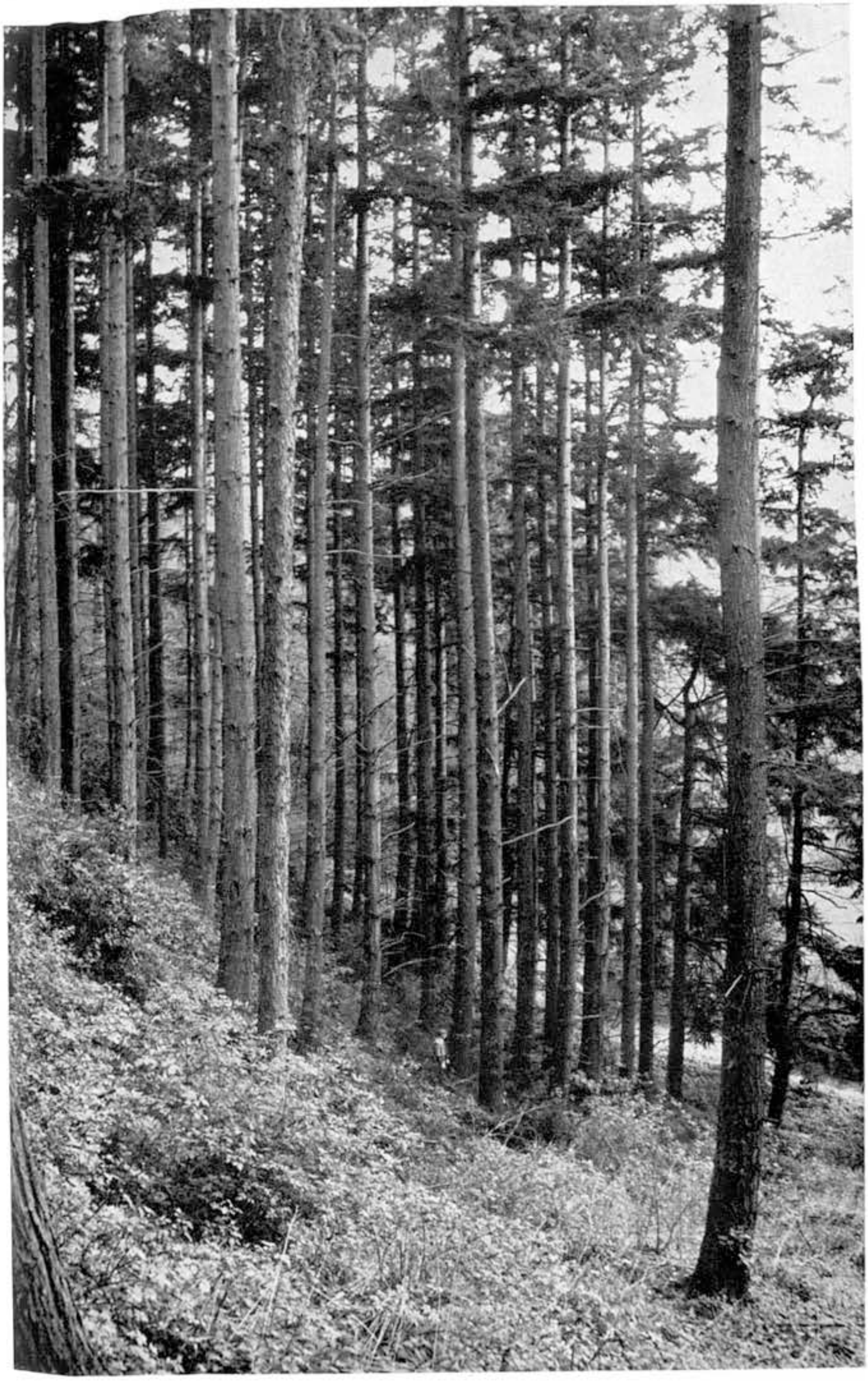


Photo 3. Christie : Douglas Fir Sample Plots. Plot E19 at Tortworth.

EDWARDS: NORWAY SPRUCE PROVENANCE EXPERIMENTS.
KIELDER FOREST EXPERIMENT No. 29. PLANTED 1936.

Photo 4. Provenance 33/1014 Staarhejm, Nordfjord, Norway March 1943. Age 7 years.

Photo 5. Provenance 32/1011 Fall, Kreuth & Berchtesgaden Forests, Bavaria, Germany. March 1943. Age 7 years.

Photo 6. The above two provenances, Norway (*on left*) and Bavaria (*on right*). July, 1952. Age 16½ years.

NEWCASTLETON FOREST. EXPERIMENT No. 4. March, 1952. Age 14 Years.

Photo 7. Provenance 34/35 Inn Valley, N. Tyrol, Austria.
Planted as 2 yr. 1 yr. 1 yr. plants.

Photo 8. In foreground and centre Provenance 36/19 Rübeland, Harz Mts. Germany.
Planted as ½ yr. 1½ yr. plants. (In background, Rumanian provenance).

Photo 9 : Provenance 36/19 Rübeland, Harz. Mts. Germany. Showing the leader killed by frost and a secondary leader replacing it, in dense *Molinia* vegetation.

Photo 10. Shaw: Tractors for Soft Ground: Front view of experimental and standard County tractor.

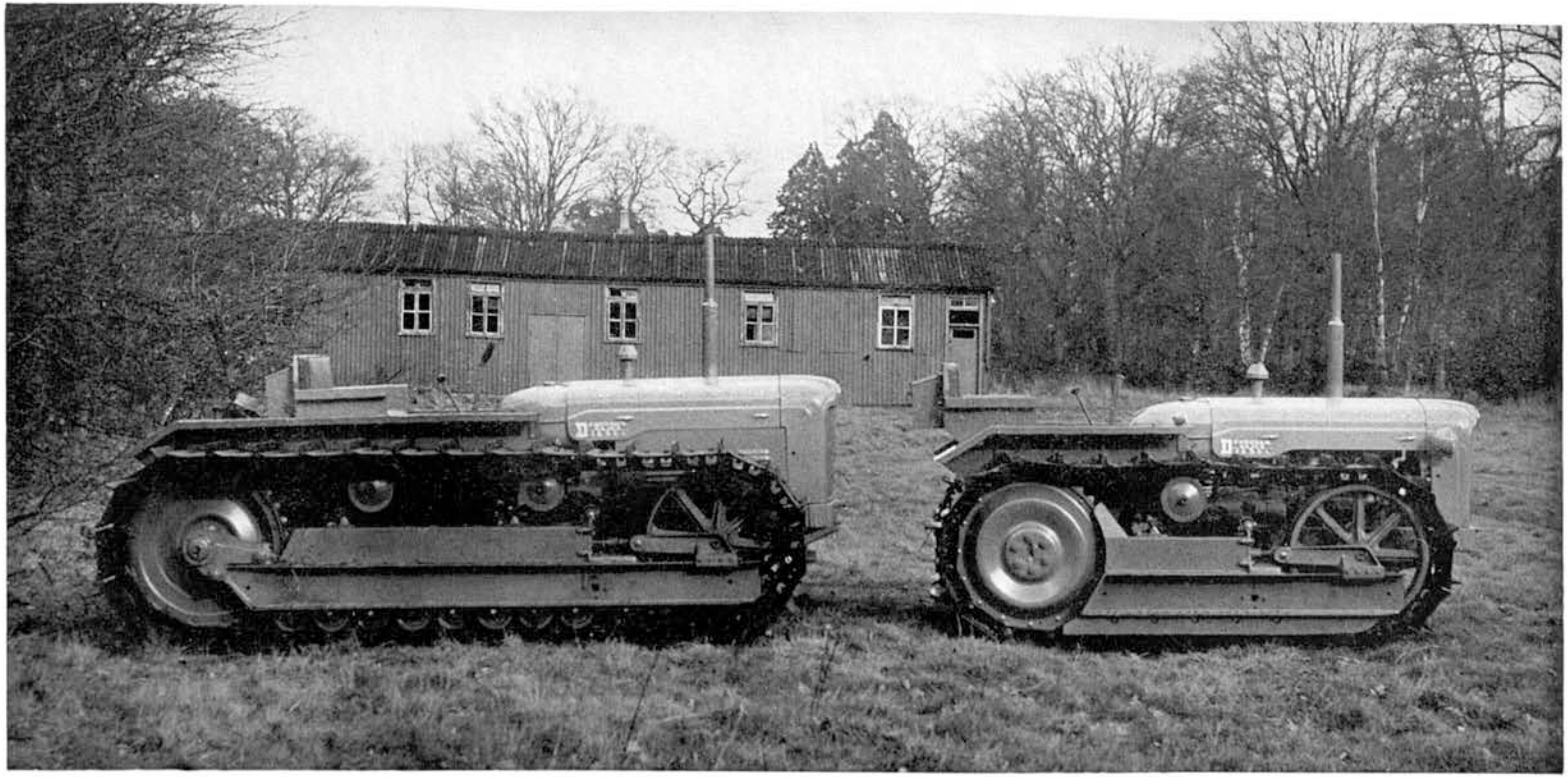


Photo 11. Shaw: Tractors for Soft Ground: Side view of experimental and standard County tractor.

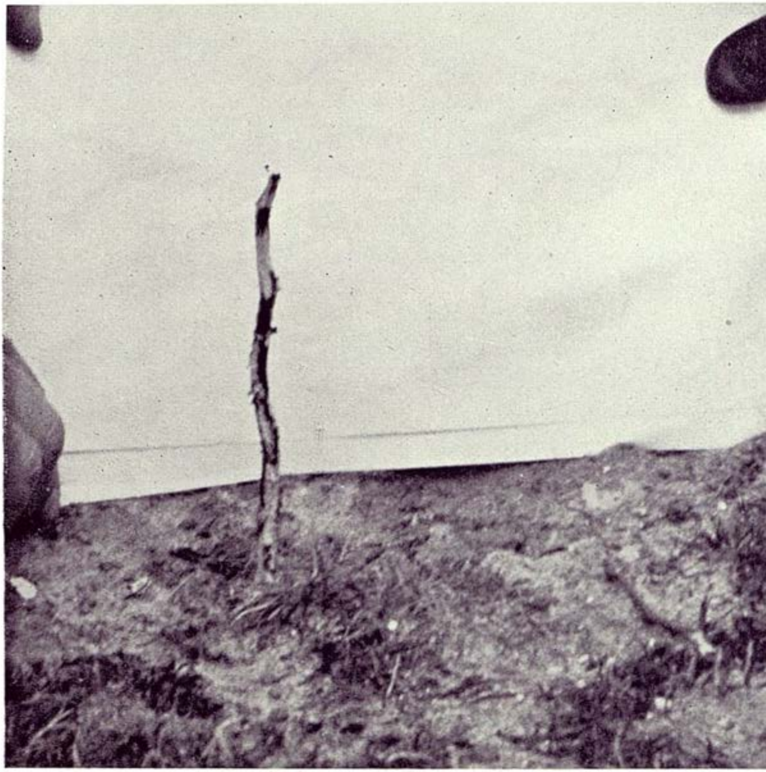


Photo 12. Close-up of an untreated and unnetted control tree of beech. The photograph was taken in March, 1953, two months after planting, and provides a typical illustration of the extent of rabbit damage at this stage.

HOLMES: PROTECTING TREES AGAINST RABBITS.

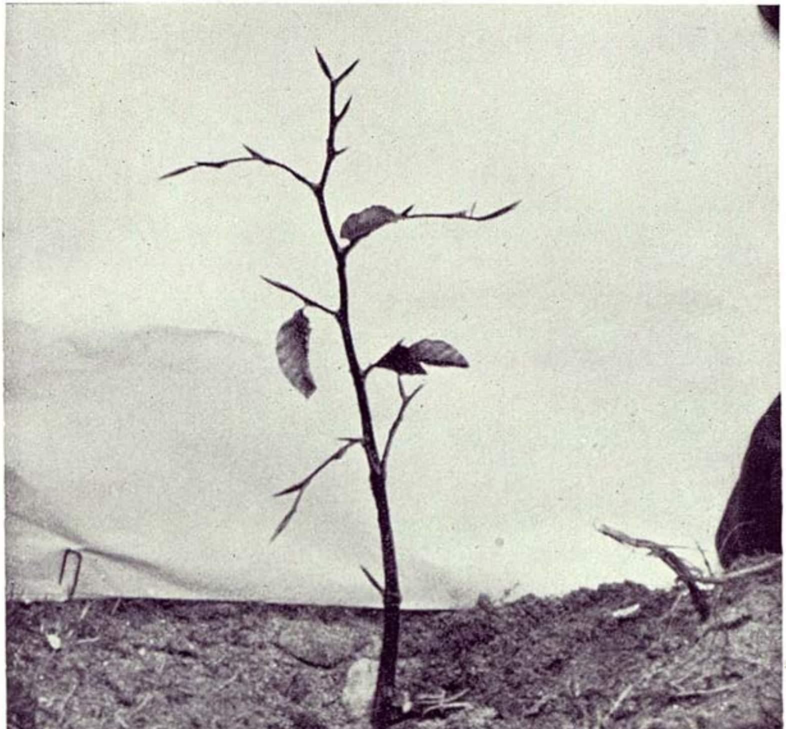


Photo 13. Close-up of a beech treated with bone oil. As for Photo 12, the picture was taken in March, 1953, two months after planting.

that Thetford is our driest extensive forest area, it is not in a class by itself, and we probably have some small forests in south-east England which are, climatically speaking, rather drier.

The temperature regime for the region is more remarkable for its short-term variations than for its long-term means. The interior of East Anglia is sometimes described as approaching continentality in climate, but the mean annual range of temperature, 24 Fahrenheit degrees, while high for Britain—is very modest by continental standards (Berlin 34°, Warsaw 39°, Saratov 60°, in similar latitudes). The mean daily range in the region is high for England, particularly in the early summer months of May and June; it may be in the neighbourhood of 20 Fahrenheit degrees for these months (Bilham 1938). This regional tendency to large daily variations in temperature is one important cause of the high frequency of spring frosts for which Thetford is notorious. Ground frosts may occur in every month of the year (Day and Peace 1946); they are common in May, and even early June; while air frosts are quite frequent in May.

Difficulties due to climate are greatly accentuated by the soils and ecological conditions obtaining prior to afforestation. The underlying geological formation is the chalk, which is here covered by a varying depth of Chalky Boulder Clay, or by blown sand, or by both these deposits with the sand on top. Flints are usually present, and sometimes chalk nodules. The Chalky Boulder Clay is scarcely penetrable by roots, and the depth of sand above is an important factor. The free draining and poorly retentive character of the soils accentuates the dryness of the locality; also such soils provide good conditions for radiation frosts. Much of Thetford prior to acquisition was derelict arable land or open heath, and a few old shelter belts of Scots pine did little to reduce the exposed character of the place, a factor of most importance, no doubt, in allowing a full measure of effectiveness to the dry east winds in spring.

Before enclosure for afforestation began, the vegetation of the Thetford area was of a grass-heath type greatly modified by the high rabbit pressure and often extremely sparse; consisting mainly of the grasses, *Festuca ovina* and *Agrostis* sp., and the sand sedge, *Carex arenaria*, with a few herbs. Where grazed nearly to extinction, the vegetation often appeared to consist of *Cladonia* species with a few rabbit-resistant herbs such as *Senecio jacobaea* and *Cynoglossum officinale*.

On enclosure and the exclusion of the rabbits the character of the vegetation changes very rapidly. A great development of the grasses occurs, and many herbs appear. *Calluna* may spread on the deeper sands. If anything, these changes towards a denser, more insulating grass mat increase the chances of radiation frosts (Day and Peace, 1946). Also the thickening vegetation increases the competition for water, an adverse change for the newly planted tree.

Choice of Species in Large-Scale Planting

The Forestry Commissioners commenced planting at Thetford in 1922. Macdonald (1939), giving an account of the operations after eighteen planting seasons, states that the initial choice of species was governed not so much by the soil as the climate, toleration of frost and drought being the essential attributes. Scots pine was planted exclusively at the outset (partly on the evidence of the local plantations and shelter belts) and proved successful. Damage by the Pine Shoot Moth, *Evetria buoliana*, encouraged the planting of the less susceptible Corsican pine as an alternative, the higher productivity of the latter being also in its favour. But shortage of seed restricted the planting of Corsican pine, and the two pines are nearly equally represented. They make up the great bulk of the forest, and have everywhere proved successful. A number of other species have been tried, without any appearing to be sufficiently reliable pioneers for large-scale planting, though some measure of success has been achieved with a few of them by the use of pine nurses. It has frequently been emphasised that a more varied choice of species at Thetford would be desirable, as a safety measure both against defoliators and fire. The special significance of beech on these soils has been recognised, and a good deal of experimental attention has been paid to the problems of establishing beech at Thetford.

Trials of Species at Lynford and Olley's Farm

The two principal trials of species in Thetford forest were commenced in 1927 at Lynford and at Olley's Farm. The sites are abandoned arable land typical enough of much of Thetford Chase, in both cases the Chalky Boulder Clay being overlaid with varying depths of sand of more recent origin. The characteristics in which the two sites appear to differ are noted below.

	Lynford	*Olley's Farm*
Elevation	100 feet.	150 feet.
Depth of free rooting soil (over Chalky Boulder Clay)	15 to 30 in. Averaging, 20 in.	16 to 36 in. Averaging, 24 in.
Other soil characteristics	Occasional flints and chalk nodules.	Rather more acid than Lynford in upper part of profile. Occasional flints, chalk nodules absent.
Shelter	Single line of old beech to East-North-East. Relatively ineffective.	Mixed conifer/hardwood shelter belt close to northern edge of trial area. Some visible benefits to crops to within 50 feet of margin.
Adverse Influences	—	Damage by hares and deer, particularly to hardwoods.

At each site a wide range of species was planted in unreplicated plots of one acre each. Site preparation and planting methods were normal for the period, the trees being planted into the bottom of shallow plough furrows. Plots were planted pure, no special effort being made at the outset to favour the more difficult species by the use of large planting stock or pine nurses. Hence the first stage of the Olley's and Lynford experiments provided a rather rigorous test of the various species as pioneers.

Under these arduous conditions a number of species failed completely, namely:—*Abies alba*, *A. procera*, *Chamaecyparis lawsoniana*, *Cupressus macrocarpa*, *Pinus jefferyi*, *Pinus radiata*, *Sequoia sempervirens* and *Thuja plicata*. No single reason can be advanced for the failure of such a diverse group. Spring frost probably played the major role with the *Abies* species, *Sequoia sempervirens*, and possibly *Chamaecyparis lawsoniana;* but winter cold, drought, and the notorious difficulty in establishing some of these species under any conditions, have all operated to varying degree.

A further group was composed of some of the common broadleaved trees; beech; sycamore; pedunculate, sessile and red oaks (*Quercus borealis*). These did not fail outright, but struggled on for many years with little prospect of reaching canopy as pure crops. Periodic cutting back by spring frost, and grazing by deer and hares, are quite limiting factors at Thetford, and it has long been understood that little success with broadleaved species is to be expected

Table 37

SUMMARY DATA FROM SAMPLE PLOTS OF CONIFERS AT OLLEY'S FARM, THETFORD

Species and Year of Measurement	Age of Crop (Years)	Main Crop (after thinning): No. of Trees Per Acre	Main Crop (after thinning): Average Ht. of Largest Trees (Ft.)	Main Crop (after thinning): Girth at 4ft. 3in. (Ins.)	Main Crop (after thinning): Over Bark Vol. Per Acre, hoppus feet	Intermediate Yield from Thinnings: No. of Trees Per Acre	Intermediate Yield from Thinnings: Over Bark Vol. Per Acre, hoppus feet	Total Crop: Over Bark Vol. hoppus feet	Mean Annual Increment: Over Bark Volume, hoppus feet
Scots pine									
March, 1948	21	1,144	31	13½	1,027	564	239	1,266	60
Sept., 1949	23	1,132	34½	14½	—	12	7	—	—
July, 1952	26	918	37½	16	1,612	214	150	2,008	77
Corsican pine									
March, 1948	21	782	34½	17	1,425	414	444	1,869	89
Sept., 1949	23	770	38	18	—	12	7	—	—
July, 1952	26	662	43	19½	2,017	108	128	2,596	100
Pinus contorta									
March, 1948	21	976	33	14	1,091	302	200	1,291	61
Sept., 1949	23	918	37	15	—	58	12	—	—
July, 1952	26	778	42½	16½	1,797	140	152	2,161	83
Pinus ponderosa									
March, 1948	21	1,140	28½	14	1,117	146	257	1,374	65
Sept., 1949	23	1,042	33	15½	—	98	1	—	—
July, 1952	26	836	39	18	1,939	206	100	2,297	88
Douglas fir									
March, 1948	21	682	44	18	1,578	324	309	1,887	90
Sept., 1949	23	582	49	19½	—	100	141	—	—
July, 1952	26	422	54½	22	2,084	160	401	2,935	113
European larch									
March, 1952	25	297	45½	21½	1,170	260	218	1,388	56
Japanese larch									
March, 1952	25	281	44	23	1,260	154	204	1,464	59

without special measures to combat these agencies. At Lynford however, the single row of old beech adjacent to the plots had attained heights of seventy-five feet, and considerable girths, a clear indication of its ultimate suitability for the site.

Thirdly we have a group of species which have achieved a measure of success. These are Scots and Corsican pines, *Pinus contorta*, *Pinus ponderosa*, Douglas fir, European and Japanese larches. To which may be added without further comment *Pinus strobus* (planted at Lynford only), this has attained twenty-eight feet in twenty years, but as usual the crop is badly affected by blister rust.

Douglas fir is represented by coastal material, and also "Fraser River" or "intermediate". The latter had no advantage over the coastal, it suffered equally from frost and lacked the compensating vigour. This is of some interest, but provides no real paradox; the "continentality" of East Anglia quite lacks the well-defined march of temperature in the interior of British Columbia.

The best data for the growth of the species are available from the Olley's area, where the crops are on the whole more uniform than at Lynford. Sample plots have been established at Olley's, and a summary of the measurements is given in Table 37. However some comment should first be made about the differences which have appeared between the crops at the two sites. These are not important, and some part of them is due more to accidental causes rather than to the slightly different range of soil depths which has already been mentioned. The Douglas fir plot at Olley's is much superior to that at Lynford, but there is a difference in seed origin, which deserves further comment. The two larch plots are also rather better at Olley's; this may be due in part to soil factors, but superior stocking is the main difference. There is little difference between the pine crops at the two sites.

Owing to war-time exigencies, we do not have as good coverage as we should like in our early records of these plots. We can however draw height-age curves which are approximately correct, and these are shown in Fig. 8.

Commenting on the above data, the height growth of Scots and Corsican pine is normal for Thetford forest, respectively and relatively. It represents, at this age, Quality Class I for both species. But it appears that Scots pine will not maintain this rate here, and the fall-off in height growth suggested by the curve is not untypical of plots elsewhere in the forest on similar depths of soil. Corsican pine appears to be increasing its advantage in height growth.

As so often happens at Thetford, Scots pine suffered severely from the Pine Shoot Moth, (*Evetria buoliana*) in the early years, but again as usual, there is little residual effect in the pole stage. Scots pine was the most easily established of the various species.

Douglas fir has made considerably the best showing in height growth and yield to date, though in height growth it only represents Quality Class IV. The rate of height increment is now slowing up somewhat, and it remains to be seen how long the crop can maintain its health and vigour on this comparatively shallow root-run above a highly calcareous substratum. On a deeper soil in this neighbourhood (West Tofts, with 36 to 48 inches of sand over the chalk) Douglas has attained fifty-nine feet in twenty-five years and eighty feet in forty-five years. (These figures are superimposed on the Olley's Douglas fir Height/Age curve, Fig. 8.)

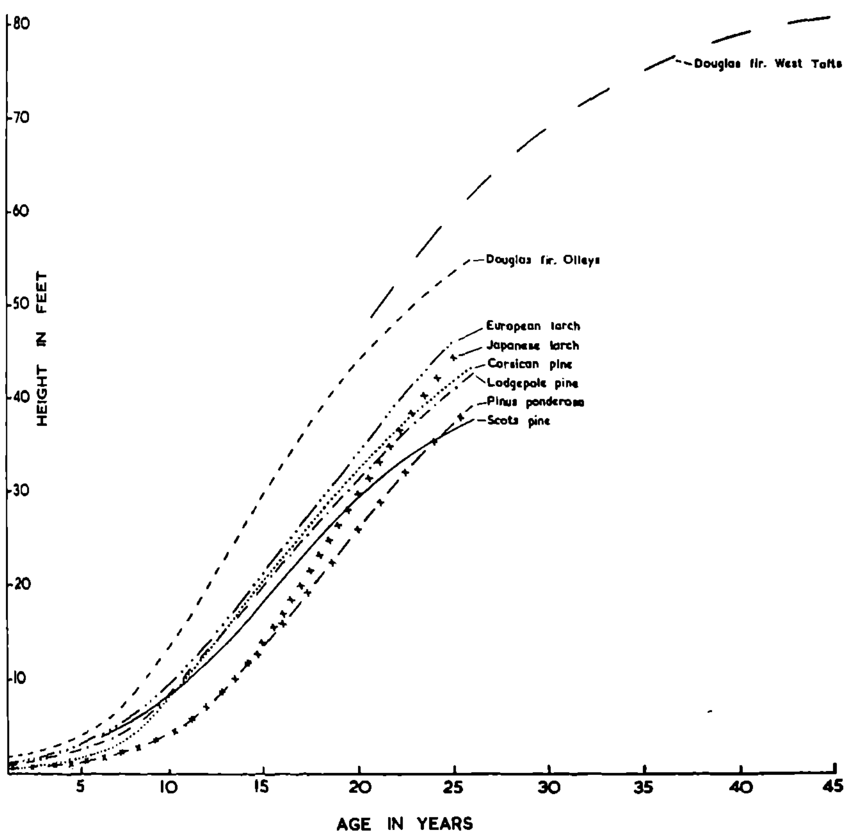


Fig. 8. Height-age curves for experimental plots of conifers at Olley's Farm, Thetford Chase. The curve for Douglas fir at West Tofts is superimposed.

Assuming similar early development to the Douglas fir at Olley's Farm (it is unlikely to have been much faster), this appears to represent better sustained growth, from about the age of twenty years onwards, than we can expect at Olley's, and it seems certain that the soil depth is the main factor.

Since Douglas fir has proved such a chancey species to establish at Thetford, the success of this plot calls for some explanation. Douglas fir has usually suffered severely from late spring frosts in this district, and this has perhaps been the main factor limiting its planting here. It has frequently been observed that individual variations in flushing date affect the degree of frost damage, though it does not appear that a late flushing habit is the complete answer (Day and Peace 1946); it has often been noted that vigorous early flushing Douglas and beech can out-grow less vigorous but later flushing neighbours even in a frosty locality. Vigour, with a general tendency to late flushing, appears to be the desired combination; there is evidence that the Douglas fir at Olley's Farm possesses both. It was observed in the early years that the plot regularly flushed rather late. Unfortunately the origin of the seed is not known, though it is certainly "coastal" in the broad sense.

European and Japanese larch have been moderately successful at Olley's. At twenty-five years of age, the European larch height growth corresponds to Quality Class II, that of Japanese larch to Quality Class III. It is to be expected that European larch will do better than Japanese larch in such a dry locality, certainly on unretentive soils. It is however interesting that Japanese larch has improved its position relative to European larch in the last ten years or so. It seems likely that this is a micro-climatic effect whereby a backward species benefits by the shelter of its more vigorous neighbours. One would expect this to show best with a species such as Japanese larch, which is critically placed for moisture requirement. Both species appear to be maintaining their height growth adequately. Neither plot was fully stocked in its early stages, hence the first thinning yields are on the low side. The crops of the two species are however good for Thetford; but they are likely to be too unreliable in establishment and insufficiently high yielding to have any important place.

The two remaining pines, lodgepole pine and *Pinus ponderosa*, provide very interesting plots. Lodgepole pine is extremely susceptible to the Pine Shoot Moth. and within the range of that pest young crops are apt to appear hopelessly deformed. Here however there has been remarkable recovery from attack, and the early thinnings have left an adequate selection of well-formed stems. This plot is from Mount Ida, British Columbia. Its rate of height growth has differed little from that of Corsican pine to date, though its yield is less. It is distinctly faster than Scots pine, and gives promise of yielding considerably more, but it is difficult to see any place for the tree in environments suited to Corsican pine, unless the timber should prove greatly superior.

Pinus ponderosa is a tree of extremely low moisture requirements, and from its distribution one would also imagine that the high summer temperatures at Thetford would suit it. It has usually proved difficult to establish, and both slow and uneven in early growth; this plot has followed the rule. It is however now growing with some vigour and improving its relative position. But it is difficult to imagine any pine approaching the general usefulness of Corsican pine on these sites.

Discussion

Of the seven conifers which have shown themselves capable of tolerating to varying degrees the early adverse conditions of spring frost and drought, Douglas fir so far appears the most productive, though the Olley's plot is, genetically. probably a lucky shot. The soils at Olley's Farm are not untypical, twenty-four inches of sand over the Chalky Boulder Clay is a common condition, though the reaction may be rather more acid than usual at Thetford for such a moderately shallow soil. The suggestion from the height age curves is that Douglas fir is beginning to fall off in vigour, as is Scots pine. While it can safely be assumed that the depth of the sand over the chalk will be the main limiting factor, it remains to be seen how far the nature of the subsoil itself will accentuate the restriction. Our general experience indicates that in this respect Corsican pine will have a great advantage over Scots pine and the larches, but the position of Douglas fir on such soils is not too well known; since its water requirements are quite low, it will probably outgrow Corsican pine on any soil deep enough to maintain a healthy root system.

One of the principal hazards to pines at Thetford, the fungus *Fomes annosus*. has not been encountered so far in these plots as a cause of mortality.* This may be partly due to the protection of stumps by creosote in the early thinnings as advocated by Rishbeth (1952). And since the pines have so far escaped, it may well be that they will have an advantage over the other conifers since they appear to be much less susceptible than most conifers to butt rot caused by *Fomes annosus*. (Peace, 1938).

* Since writing, a few deaths from *Fomes annosus* have occurred in the *Pinus ponderosa* plot.

Later Developments

The plots which failed outright at both Lynford and Olley's were replanted in 1930 and 1931 with birch and common and grey alder (*Alnus incana*), the intention being to provide pioneer crops to shelter re-introductions of some of the failed species. The effort has been only partly successful, the take and growth of birch and alders being poor, and in spite of constant beating-up only irregular and open crops have resulted. In twenty years the best of the birch attained only twenty feet, and the grey and common alders twenty-five and sixteen feet respectively. (It is of interest however that nearby at Mousehall, on deeper sand, grey alder attained some forty feet in the same time.)

However, the birch and alder plots have been utilised since 1951 for underplanting, and species so far attempted include the following: *Abies concolor, A. grandis, A. nordmanniana, A. lasiocarpa, Picea omorika, Sequoia gigantea, Chamaecyparis lawsoniana, Thuja plicata, Tsuga heterophylla, Nothofagus procera.*

The expected advantages of cover in reducing the frost hazard, and in mitigating the drought factor by eliminating the sward, are already very apparent in the excellent early growth of most of the species; though it remains to be seen what will happen in the event of a late frost comparable with that of May 1935. It may however be remarked that quite apart from local shelter, there must be considerable local climatic modifications due to the Thetford plantations, which now cover some 40,000 acres. One would expect some diminution in the range of daily temperature, and while it is unlikely that we can insure against the exceptional frost, some part of the difficult characteristics have been changed; the indications are that the choice of species can be widened to include many trees which were only barred by the temporary factors obtaining when the whole region was unplanted breckland.

Further encouragement is also given by the performance of a number of the less common species elsewhere in the vicinity. At the neighbouring King's Forest, under similar soil and climatic conditions, some have had a quite surprising degree of success. (The frost hazard is here somewhat smaller than over much of Thetford for reasons of topography). These include *Nothofagus obliqua*, a few of which have attained over thirty feet in eighteen years; red oak (*Quercus borealis*), *Abies nobilis* and *Picea omorika* of the same age also show respectable growth. It is of interest that the *Nothofagus* compares favourably with adjacent beech. These species are growing satisfactorily on sand of twenty-four to thirty-six inches in depth over the chalk.

The question of how different species may modify the soil conditions has recently been studied by Ovington (1953), who has taken the Olley's plots as one of a series of trials of species on contrasting sites for this purpose.

Summary

The principal characteristics of the Thetford environment are briefly described. Climatic dryness is accentuated by non-retentive soils; the dry nature of which accentuates the risk of radiation frosts, as also does the insulating sward. Spring frost and drought are the main restrictions for choice of species in pioneer planting. At Olley's and Lynford some seven conifers (Scots, Corsican and lodgepole pines, *Pinus ponderosa*, Douglas fir and Japanese and European larches) have had varying degrees of success. Douglas fir has succeeded remarkably well at Olley's Farm, though some reservations are made. A number of frost-tender or otherwise unsuitable species failed outright, and no

broadleaved species succeeded in the first instance. Later introductions into pioneer crops show some promise, and it is apparent that the choice of species is much wider when the ecological accentuations of the frost and drought factors are removed.

REFERENCES

BILHAM, E. G. *The Climate of the British Isles.* Macmillan, London, 1938.

DAY, W. R., and PEACE, T. R. *Spring Frosts.* Forestry Commission Bulletin No. 18. (Second Edition), 1946.

GLASSPOOLE, J. The Reliability of Rainfall Over the British Isles. *Trans. Inst. Water Engineers*, 35, 1930.

OVINGTON, J. D. Studies of the Development of Woodland Conditions Under Different Trees. I. Soils pH. *Journ. Ecol.* XLI, No. 1, 1953.

PEACE, T. R. Butt Rot of Conifers in Great Britain. *Quart. Journ. For.* XXXII, 81, 1938.

PENMAN, H. L. "Evaporation over the British Isles." *R. Met. Soc. Quart. J.*, 76 (1950), 372-83.

RISHBETH, J. Control of *Fomes annosus.* *Forestry* XXV, 1952.

RISHBETH, J. Observations on the Biology of *Fomes annosus*, with particular reference to East Anglian Pine Plantations. *Annals of Botany*, XIV, XV, 1950, 51.

WATT, A. S. Studies in the Ecology of Breckland. 1. Climate, Soil and Vegetation. *Journ. Ecol.*, XXIV, 1936.

MACDONALD, J. Thetford Chase. *Forestry*, XIII, No. 1, 1939.

NORWAY SPRUCE PROVENANCE EXPERIMENTS

By M. V. EDWARDS,
Silviculturist (North)

A number of small experiments are in existence which illustrate the reaction of certain continental provenances of Norway spruce (*Picea abies* (L.) Karst.) to conditions in Britain. Considered alone, these experiments are far from complete or conclusive, but as they are now beginning to be confirmed by the more comprehensive International Norway spruce experiment of 1938, which was planted at The Bin forest, Aberdeenshire, in 1942, their results are of some interest.

A group of the experiments was planted in Kielder and Newcastleton forests on the border between Scotland and England in the years 1936 to 1938. These forests form part of a very considerable area of grassland dominated by the purple moor grass, *Molinia caerulea* (L.) Moench., which indicates suitable sites for afforestation with spruce.

Table 38

SURVIVAL, HEIGHT GROWTH AND DATE OF FLUSHING OF NORWAY SPRUCE PROVENANCES AT KIELDER FOREST, EXPERIMENT NO. 29, 1936 PLANTINGS

Identity No.	Provenance	At time of planting		First season Loss %	Nov., 1939 Age 4 years	May, 1944 Age 8 years		May, 1948 Age 12 years Mean Ht. feet
		Age and Type	Approx. Size ins.		Mean Ht. ins.	Mean Ht. ft.	Approx. % flushed on May 17th	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
32/1028	Anajoki, Finland....	2+2	7	5	8	2.2	60	4.2
32/1052	Kronoberg, Sweden	2+2	7	2	13	3.3	70	6.2
33/1014	Nordfjord, Norway	1+2	7	1	12	2.9	80	5.5
32/1003	Forres, Morayshire	1+2+1	9	0	20	4.3	28	7.5
31/64	Harz Mts., Germany	2+2+1	10	0	24	4.9	32	8.7
32/1021	Black Forest, Germany	2+2	12	1	19	4.6	35	8.3
32/1020	Haut Rhin, France	2+2	10	4	19	4.3	45	8.2
32/1011	Bavaria, Germany	2+2	12	0	21	4.6	27	8.6
32/1010	Böhmerwald, Czechoslovakia	2+2 & 2+1+1	11	0	24	4.8	15	8.2
32/1012	Carpathian Mts., Czechoslovakia	2+2	12	1	19	4.7	12	9.5

Notes: (1) Above data are the means of two to four replicates on a uniform *Molinia caerulea* grassland, not arranged in formal blocks. Analysis of variance not possible.
(2) Col. (2) Plants of Anajoki, Finland, provenance reported as being very poor and undeveloped in both needles and roots on receipt from nursery. Anajoki is now part of the U.S.S.R.
(3) Col. (9) Data of May, 1948, measured after the fire which killed but did not obliterate the plants.

SURVIVAL AND MEAN HEIGHT OF NORWAY SPRUCE PROVENANCES AT KIELDER FOREST, IN EXPERIMENT NO. 29, 1938 PLANTINGS

Table 39

Identity No.	Provenance	At time of planting		First Season Loss %	Oct., 1946 Age 9 years Mean Ht. ft.
		Age and Type	Approx. Size ins.		
34/42	Black Forest, Germany	2+2	16	5	4.2
33/11	Austria	2+2	12	3	3.6
34/35	Inn Valley, Austria	2+2	12	4	3.6
34/56	Mt. Bihor, Rumania....	2+2	14	7	4.0
		Standard Error of the Means			±0.18
		Differences—not significant.			

Five replications of randomized blocks, 100 plant plots. Burnt in 1948.

SURVIVAL AND MEAN HEIGHT OF NORWAY SPRUCE PROVENANCES AT KIELDER FOREST, IN EXPERIMENT NO. 29, 1939 PLANTINGS

Table 40

Identity No.	Provenance	At time of planting		Oct., 1946 Age 8 years Mean Ht. ft.
		Age and Type	Approx. Size, ins.	
35/30	Jutland, Denmark	2+2	9	3.4
35/31	Black Forest, Germany	2+2	8	3.5
35/41	Eysack Valley, Italy	2+2	8	3.3
		Standard Error of the Means		±0.18
		Differences—not significant.		

Mean of three replications of randomised blocks, 100 plant plots. Burnt in 1948.

SURVIVAL, FROST DAMAGE AND HEIGHT GROWTH OF NORWAY SPRUCE PROVENANCES AT KIELDER FOREST, IN EXPERIMENT NO. 37, 1939 PLANTINGS

Table 41

Identity No.	Provenance	At time of planting		First Season Loss %	Oct. 1946 Age 8 yrs. Mean Ht. ft.	Plants damaged by frost Dec. '47 %	Jan., '53 Age 14 yrs. Mean Ht. ft.
		Age & Type	Approx. Size ins.				
35/30	Jutland, Denmark	2+2	9	0	3.5	8.2	7.0
35/31	Black Forest, Germany	2+2	7½	0.3	3.6	11.4	6.4
35/41	Eysack, Italy	2+2	7½	0	3.7	1.2	7.9
		Standard Error of the Means				±2.6	±0.85
		Differences—not significant.					

Mean of two replications. Samples of 100 plants per plot.

The provenances employed ranged from Finland, Sweden, Norway and Denmark through the Harz Mountains, Bavaria, and the Black Forest in Germany, the Central Alps, Northern Italy, the North Tyrol district of Austria. and Czechoslovakia, to Rumania. Details are given in Table 45. The results of the assessments are given in the tables.

Table 42

SURVIVAL AND HEIGHT GROWTH OF NORWAY SPRUCE PROVENANCES AT KIELDER FOREST, IN EXPERIMENT NO. 38, 1940 PLANTINGS

Identity No.	Provenance	At time of planting		First Season Loss %	Jan., 1946 Age 6 years Mean Ht. ft.	Damaged by frost Spring 1947	June, 1953 Age 13½ years	
		Age & Type	Approx. size, ins.				Mean Ht. ft.	Loss %
36/15	Black Forest, Germany	2+2	5—11	1.30	2.3	9	6.2	8
34/35	Inn Valley, Austria	2+2	5—13	0.35	2.2	5	6.3	7
35/28	Inn Valley, Austria	2+2	5—11	1.50	2.2	1	6.9	8
36/60	Rumania	2+2	4—14	3.20	2.1	8	5.8	15
						S.E. of means Differences not significant.	±0.3	Not significant

Seven replications of randomized blocks. Samples of 64 plants, plot size irregular.

The experiments at Kielder forest, in Northumberland, utilised plants of comparable age and not dissimilar size. The results in general (Tables 38 to 42) showed little difference in rate of growth between the provenances with no significant differences at ages of 8 to 13 years, although one Rumanian provenance (34/56) attracted attention as showing outstanding promise, being vigorous, evenly grown and of a healthy colour. On the other hand the Scandinavian provenances were obviously least successful and their yellower colour and less vigorous appearance was frequently noted in inspection reports. The data in Table 38 show that all the plants of Scandinavian provenance were smaller, although of equal age, when planted; their early losses were larger and their mean height by 1948 less than that of the other provenances. An assessment in 1944 indicated that the Scandinavian provenances tended to flush earlier. Differences between the other provenances from the rest of Europe were small and certainly not significant, but the acceleration in growth of the Carpathian Mountains provenance may be noted. The differences at an age of 7 years between an average Scandinavian provenance (Norway) and an average Central European one (Bavaria) are shown in Photographs 4 and 5. Photograph 6 shows the same provenances at an age of 16½ years, by which time the Bavarian plot had completed canopy.

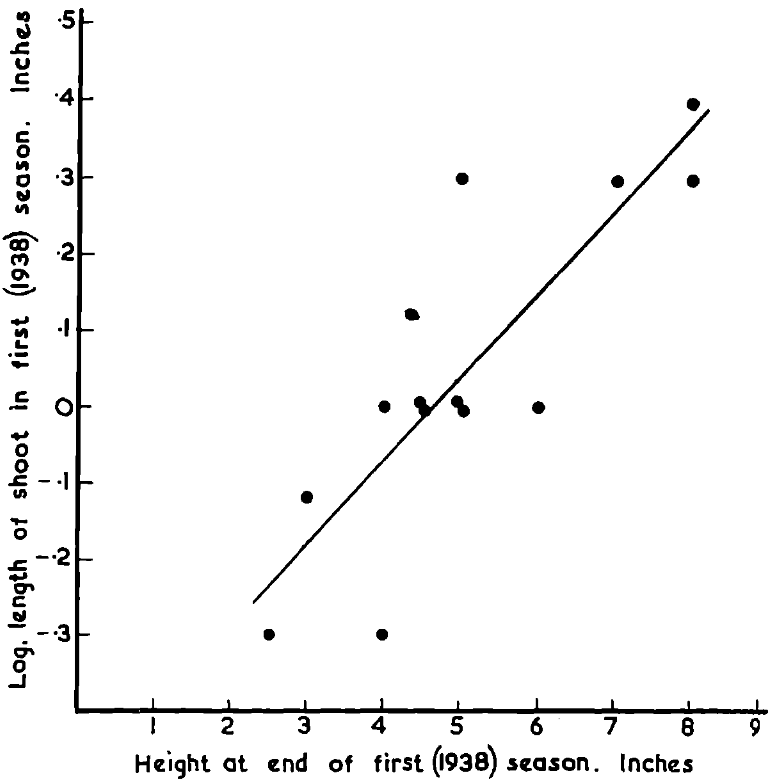


Fig. 9. Relationship between Size of Plant and the Logarithm of the Shoot Length in the First Season of Growth. Newcastleton Forest, Expt. No. 4.

In the experiment at Newcastleton forest, the plants used were not all of comparable age and size because the seed had not all been available for sowing in the same year. The age groups, counting from the time of sowing, ranged from five years down to two years, and the number of transplantings that had taken

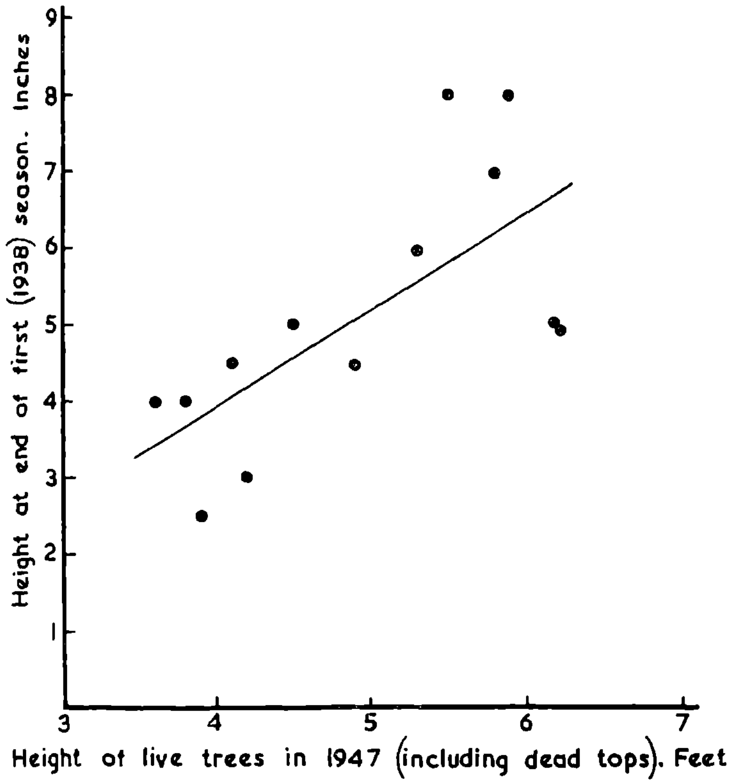


Fig. 10. Relationship between Height of Trees in 1947, and their Height in 1938. Newcastleton Forest, Expt. No. 4.

place varied with each lot. At the time of planting, the plants were classified into four size groups, viz., small, fairly small, medium and large. These sizes corresponded roughly with the ages of the plants, except in the case of two provenances raised in the Royal Botanic Garden, Edinburgh, which were larger for their age than the remainder (Id. Nos. 35/31 and 35/41 (see Table 43)) and the Swedish provenance (Id. No. 32/542), which although the oldest was not large. At the end of the first season's growth in the forest the mean heights of the plants and the growth of the shoots in each plot were estimated. Dead plants were also counted. As may be seen from Table 43 and Fig. 9, there is a linear relationship between the logarithm of the length of the shoot and the height of the plants, and this regression is highly significant. The failures in the small two-year-old plants were much higher than in the older ones, and losses in the four- and five-year-old plants were in general higher than among the three-year-old plants. These established themselves most successfully. These differences have proved most important in following the subsequent history of the different provenances. That they persisted is shown in Fig. 10, in which the mean total height in 1947, at the age of 10 years, is still closely correlated with the size at the time of planting. (Correlation coefficient 0.48, significant at the 1 per cent level of probability.)

An assessment in October 1943 showed that losses had increased, the failures in the provenances consisting of three- and four-year-old plants totalling 10 per cent and 7 per cent respectively, and the mean losses in the provenances represented by two-year-old plants having risen to 37 per cent. In the dense grass

SURVIVAL, HEIGHT GROWTH, FROST DAMAGE AND DATE OF FLUSHING OF NORWAY

Table 43

Identity No.	Provenance	At time of planting		Data at end of first (1938) season			Octo... At ag...
		Age and Type	Size	Ht. ins.	Shoot ins.	Loss %	Ht. ft.
32/542	Ostersund, Sweden	5 years: 2+1+1+1	L	4	½	4.0	2.0
		4 years:					
34/42	Black Forest, Germany	2+1+1	L	7	2	3.3	3.2
33/11	Austria	2+1+1	L	5	2	1.3	3.6
34/35	Inn Valley, Austria	2+1+1	L	6	1	4.0	3.0
34/54	Eysack, Italy	1+2+1	L	5	1	8.0	2.3
34/56	Mt. Bihor, Rumania	2+1+1	L	5	1	5.3	3.2
	Mean			5½	1½	4.4	3.1
		3 years:					
35/30	Jutland, Denmark	2+1	M	4½	1	3.3	2.7
35/31	Black Forest, Germany	2+1	L	8	2½	1.3	3.2
35/28	Inn Valley, Austria	1+1+1	M	4½	1	3.3	2.1
35/41	Eysack, Italy	2+1	L	8	2	2.0	3.2
	Mean			6¼	1½	2.5	2.5
		2 years:					
36/19	Harz Mts., Germany	½+1½	S	2½	½	22.7	2.0
36/15	Black Forest, Germany	1+1	FS	4	1	18.0	2.3
36/17	Central Alps	½+1½	S	3	¾	15.3	2.1
	Mean			3	¾	18.6	2.1
	†Standard Errors of Means: between provenances						±0.1
	between age groups						±0.0
	†Difference necessary for significance: Between provenances 5% level						0.3
	1% "						0.3
	Between age groups 5% "						0.1
	1% "						–

L—Large; M—Medium; FS—Fairly Small; S—Small.

*Beating up had been carried out in these plots after the 1943 count, thus reducing

vegetation on this site serious failures are common when small plants are used, probably arising from the effect of frost, accentuated by the dense grass cover acting as an insulation from the warmer soil below and by radiation of heat from the grass blades themselves. (Photographs 7 and 8.)

On the 26th April, 1945, there was an unusually severe late frost which caused a great deal of damage to the plants. A report in May 1946 noted that the damage was least in the Rumanian and Black Forest provenances (34/56, 34/42 and 35/31) and that these appeared to flush later than the others. By April, 1947, it was clear that serious damage had been done both to this experiment and to some 400 acres of forest surrounding it. The experiment is situated on a "frost shelf" where the cold air had lain, filling up the valley to a height slightly above the elevation of the experiment. Some of the trees were killed outright and on others the topmost two or three feet of the leading shoots were killed. By that

ENANCES AT NEWCASTLETON FOREST, EXPERIMENT NO. 4, 1938 PLANTINGS

May 1947 Data at age of 9 years					Differences between Losses % 1947 and 1943	Index of Flushing 1947		
of live (incl. tops) ft.	Ht. of live tip ft.	Length of dead top per live tree ft.	Loss %	Percentage of surviving trees which showed dead tops		May 12th	May 23rd	June 6th
3.6	3.2	0.4	10	10	3	1.5	2.0	4.0
5.8	5.4	0.4	7	25	1	1.0	1.0	3.4
6.2	6.0	0.2	2	16	0	1.4	3.0	4.0
5.3	5.0	0.3	11	20	2	1.6	2.6	4.0
4.5	4.2	0.3	24	25	6	1.0	1.2	3.2
6.2	6.1	0.1	6	5	0	1.0	1.8	3.6
5.6	5.3	0.3	10	18	2	—	—	—
4.9	4.4	0.5	7	30	2	1.0	1.8	3.6
5.9	5.6	0.3	6*	19	1*	1.0	1.2	3.2
4.1	4.0	0.1	21	6	2	1.0	1.8	3.8
5.5	5.2	0.3	5*	22	2*	1.8	3.0	4.0
5.1	4.8	0.3	10	19	2	—	—	—
3.9	3.0	0.9	54	30	8	1.2	2.4	4.0
3.8	3.0	0.8	31	41	6	1.0	1.6	4.0
4.2	3.7	0.5	41*	20	5*	1.0	1.4	3.6
4.0	3.2	0.7	42	30	6	—	—	—
0.19	±0.26	—	—	—	5 replications of randomized blocks.			
0.10	±0.13	—	—	—				
0.54	0.75	—	—	—	30 plant plots.			
0.73	1.00	—	—	—				
0.19	0.39	—	—	—				
0.26	0.51	—	—	—				

Excluding 32/542—Sweden, of which only two replications are represented.
7 relative to other provenances.

time new shoots were springing up from below, gradually taking the place of the leaders (Photograph 9). In May, 1947, an attempt was made to measure the extent of the damage. Two height measurements were made, the first being to the tip of the leading shoot, whether live or dead, and the second to the top of the living portion only. This measurement was made on all trees showing signs of life, but not on trees killed outright. From these two measurements it is possible to deduce the mean length of the top of the stem which had been killed back, ignoring the probability that some regrowth in the intervening seasons might have reduced it slightly, though equally, in all plots. Examination of the experiment suggested that the greatest damage had been done to the smallest trees, and the data given in Table 43 and Fig. 11 show that there is a negative correlation between the length of dead leader and the mean height of the plants in the plot (coefficient 0.33 significant at the 5 per cent level of probability). The most severe damage was suffered by the provenances represented by the plants two years old when planted, which were still the smallest in the experiment. These had a mean height of about three feet at the time of the frost, and this appears to have been below the critical general level of the frosty air. Provenances composed of plants originally larger, and which were over three feet tall, escaped the worst of the frost damage.

A comparison between the assessments of October 1943 and May 1947 gives an indication of the number of plants killed outright by the frost and therefore not included in the height assessment. (It is unlikely that the plants would have died so long after planting except on account of such an unusual calamity as the frost.) The data so obtained agree with the data for the killing of the leading shoots. The two provenances which had reached a mean height of six feet suffered the least loss; and the group of provenances two years old when planted, only some three feet high, had many losses. This relationship is logarithmic and the regression between the mean height and the logarithm of the losses is highly significant. See Fig. 12. Some apparent discrepancies, such as the small loss in length of leading shoot for the Inn Valley provenance (35/28) shown in Fig. 11 are compensated for by the larger numbers of plants killed outright, and the two measures of frost resistance should be considered together.

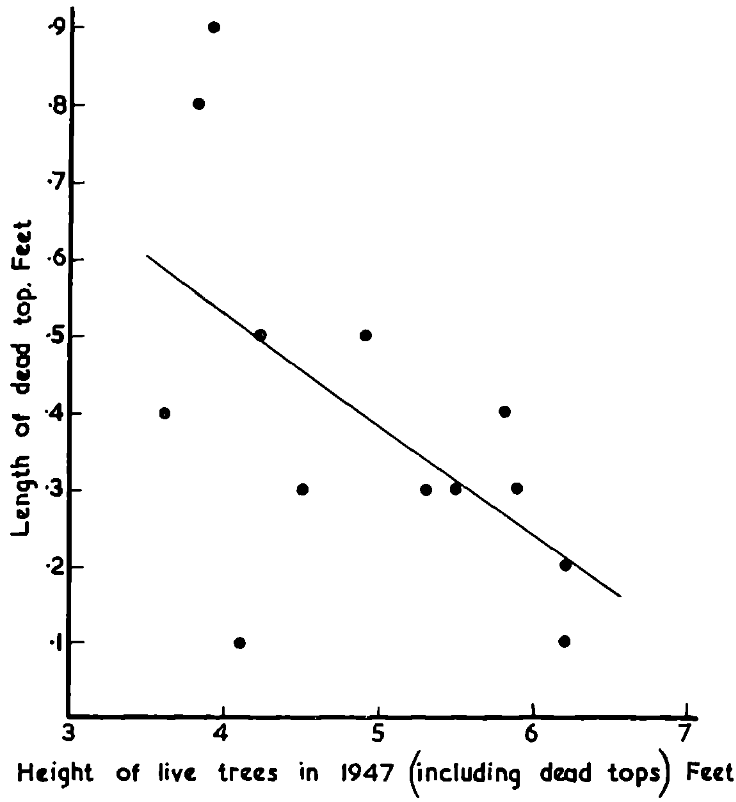


Fig. 11. Relationship between Height of Plant and Length of Top Damaged by Frost. Newcastleton Forest, Expt. No. 4.

In May 1947, while the other assessments were in progress, the stage of flushing of the new needles was examined. Each plot was classified every few days and an approximate mean for the whole plot was recorded, the notation 1

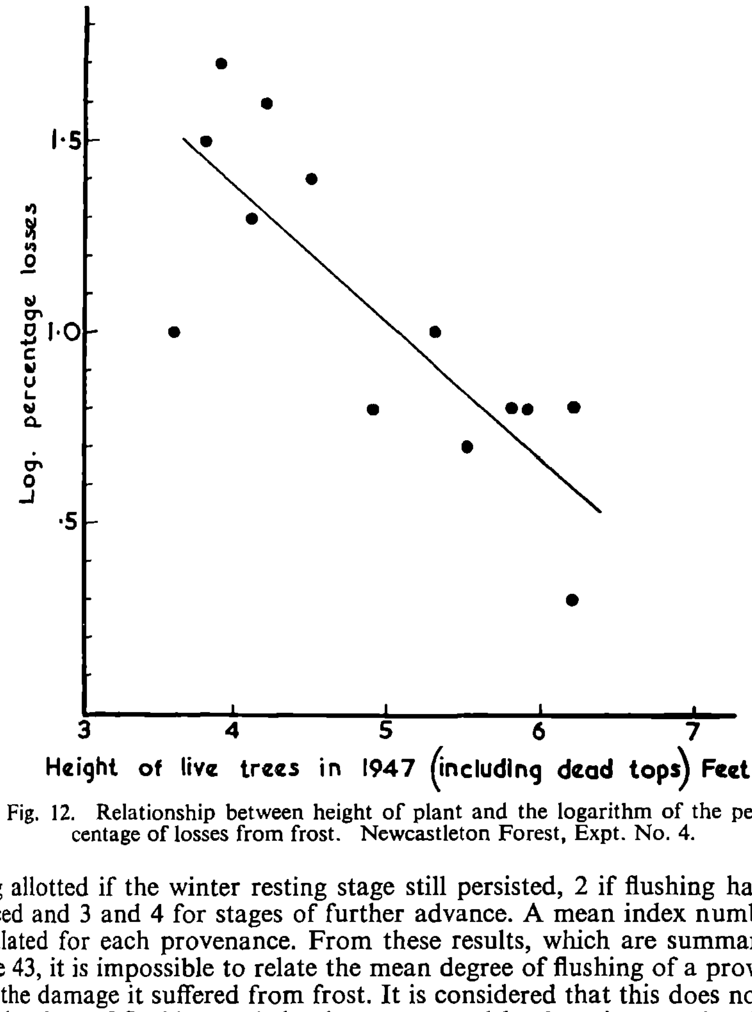


Fig. 12. Relationship between height of plant and the logarithm of the percentage of losses from frost. Newcastleton Forest, Expt. No. 4.

being allotted if the winter resting stage still persisted, 2 if flushing had commenced and 3 and 4 for stages of further advance. A mean index number was calculated for each provenance. From these results, which are summarised in Table 43, it is impossible to relate the mean degree of flushing of a provenance with the damage it suffered from frost. It is considered that this does not mean that the time of flushing and the damage caused by frost is not related to the provenance, but rather that the method of assessment was too crude; flushing assessment methods have since been changed to take account of the size of each tree.

In 1952 the plots were again examined and their general success as judged by mean height and even growth confirmed the data of 1947, showing that the four best provenances are: Rumania, Austria, and the two Black Forest provenances 35/31 and 34/42. The other Black Forest provenance (36/15) and the two other provenances which were all represented by young and small plants when planted, were not only the shortest, but the plots contain very many blanks due to early failures. The remaining provenances were intermediate between the above two extreme groups.

It is impossible to draw any firm conclusions as to the relative suitability of the various provenances for the site at Newcastleton Forest, because of the different ages and sizes of the plants used in the experiment. If the five provenances of four-year-old plants, which were all of approximately equal size when planted, are considered by themselves, then there are indications that the more easterly provenances from Rumania and Austria are superior both in growth and frost resistance, followed by the Black Forest provenance. The North Tyrol provenance is slightly inferior and the North Italy provenance the least successful. Among the four provenances of three-year-old plants, the differences are not very great, and only one provenance suffered considerable casualties. This was the North Tyrol provenance, but again the original plants were the smallest of the group. It is clear that the size of the plants when the severe frost occurred was related to their size when planted, and that the damage caused by the frost was chiefly related to the size of the plants irrespective of their provenance. It is not possible to deduce from the data available whether the Austrian and Rumanian provenances are intrinsically more frost-hardy, or whether their hardiness was due to their greater vigour which had raised them above the level of the very cold air near the ground.

Seed from some of the same collections was also used in an experiment at Leanachan Forest, north-east of Ben Nevis in Inverness-shire. In this case the fastest growing provenance is one from Thetford in Norfolk. This is the only home seed collection present, and as has frequently happened in the case of European larch, such British-grown seed often gives the best results. Second to it, though not significantly shorter, are the Rumanian provenances and one from Denmark, which, like the Thetford provenance, is not a native one. German, Italian and Austrian provenances were inferior. (Table 44.)

HEIGHT GROWTH OF NORWAY SPRUCE PROVENANCES AT LEANACHAN FOREST

Table 44 Experiment No. 1. Planted in 1938

Identity No.	Provenance	January, 1953, Age 15 years Mean Ht. feet
35/30	Jutland, Denmark	4.4
34/1023	Thetford, Norfolk	5.0
34/42	Black Forest, Germany	4.1
35/31	ditto ditto	3.5
35/28	Inn Valley, Austria	3.1
35/41	Eysack Valley, Italy	3.7
34/56	Mt. Bihor, Rumania	4.4
	S.E. of means	± 0.34
	Difference necessary for significance at 5% of probability	1.1

Five replications of randomized blocks, 30-plant plots.

Another comparison between spruce of different provenances is afforded by three forest plots at Bedgebury Forest, Kent. Though the site on which the plots are situated is fairly uniform, the plants used were not, having been raised in different nurseries, and one lot (Harz Mountains, Germany) was planted one year later than the other two (Lower Austria and Invergarry, Inverness-shire) and at a different spacing. It is of interest to note that, as shown in Fig. 13, the growth rates of all three plots have been similar.

In considering the results of all these experiments it must be remembered that the various seed collections represented are not necessarily typical of the regions from which they came. Many of them were ordinary commercial collections of provenances bearing the same name (e.g. Inn Valley, Austria, 34/35 and 35/28 and Rumania 34/56 and 36/60), and strictly speaking the results of these

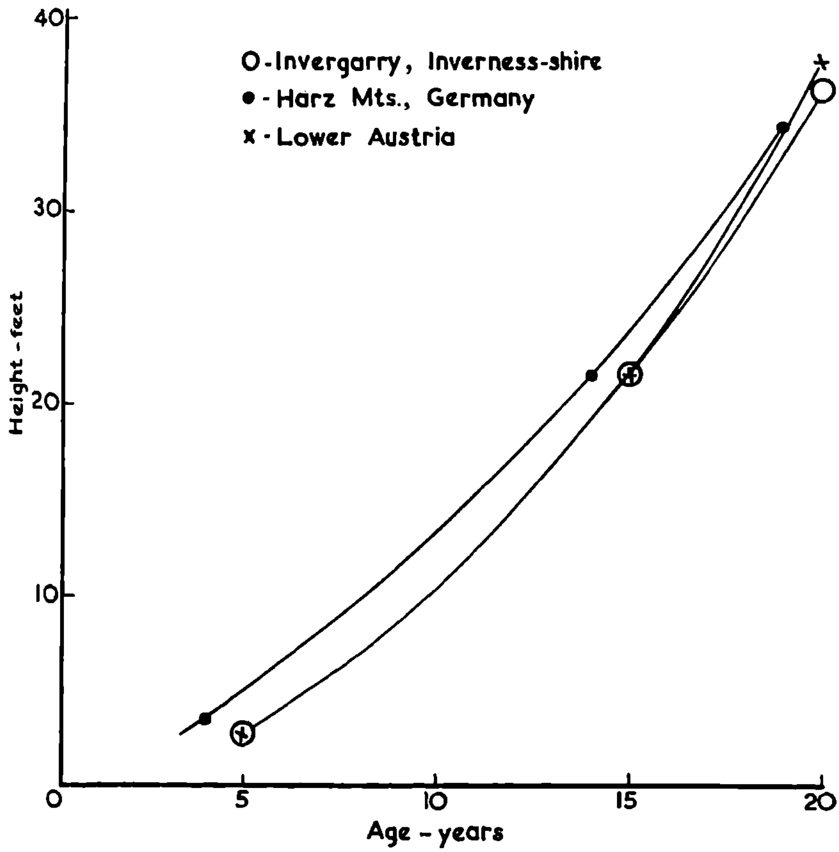


Fig. 13. Growth Curves of the Three Provenances at the Bedgebury Forest Plots.

experiments apply only to the particular collections of seeds employed, which are detailed in Table 45. There are not enough data yet available to be able to estimate how closely these results will be repeated with other seed collections, although the younger International experiment at The Bin Forest suggests that in general they will be found to be reliable.

The general conclusions to be drawn from these experiments are firstly, that it is essential for the plants to be raised under comparable conditions in the nursery if differences between provenances are to be distinguished within a few years. Provided that different provenances grow at comparable rates in the nursery, all the plants used should be of the same age and type. If not of the same age and type, then in any case it will take a matter of some years for differences due to external causes to disappear and inherited ones to become evident, and in extreme cases, as at Newcastleton, so much damage may have happened that a reliable contrast between provenances will never be obtained.

Secondly, excluding differences of age or type of plants used in establishing the forest plots, there are many indications that Norway spruce of south-east European provenances grows more vigorously than any others tested. Provenances from Finland, Norway and Sweden have been the least successful, especially those from the most northern regions. Provenances from German and Alpine sources are intermediate in vigour of growth.

DETAILS OF THE PROVENANCES OF NORWAY SPRUCE

Kielder Forest, Experiment No. 29	Planted 1936, 1938 and 1939
,, ,, ,, ,, 37	,, 1939
,, ,, ,, ,, 38	,, 1940
Newcastleton ,, ,, ,, 4	,, 1938
Leanachan ,, ,, ,, 1	,, 1938
Bedgebury, Forest Plots.	

Table 45

Identity No.	Provenance	Elevation feet	Latitude	Longitude
32/1028	Anajoki, Finland (now U.S.S.R.)	240	61°27′	29°39′E
33/1014	Staarhejm, Nordfjord, Norway*	sea level	61°55′	5°46′E
32/542	Östersund, Jämtland, Sweden	300–1000?	63°10′	14°41′E
32/1052	Hvittaryd, Kronoberg, Sweden	1600?	56°55′	13°50′–14°0′E
35/30	Jutland, Denmark*	under 300	56°–57°	9°–10°E
32/1003	Forres, Morayshire, Scotland*	100–200?	57°36′	3°35′W
34/1023	Round Plantation, nr. Mundford, Thetford, Norfolk, England* (Lot A. One tree with markedly ascending branches and stiff twigs)	100	52°30′	0°38′E
31/64	Braunlage, Harz Mts., Germany	1600–2000	51°43′	10°37′E
36/19	Rübeland State Forest, Harz Mts., Germany	1500	51°44′	10°52′E
32/1021	Altensteig, Black Forest, Germany	1600–2000	48°35′	8°36′E
35/31	Freudenstadt — Horb — Nagold, Black Forest, Germany	1470–2300	48°27′–32′	8°25′–44′E
36/15	ditto ditto ditto	ditto	ditto	ditto
34/42	Black Forest, Germany	—	48°–49°	8°–9°E
32/1020	Stosswihr communal forest, Colmar, Haut-rhin, France	1600–2000	48°3′	7°7′E
32/1011	Fall, Kreuth and Berchtesgaden forests, Bavaria, Germany	2500–4000	47½°	12°–13°E
34/35	Inn Valley, N. Tyrol, Austria	1950–2600	47°–47½°	10°–12°E
35/28	ditto ditto	ditto	ditto	ditto
34/54	Eysack (Isarco) Valley, Trentino, Italy	2300–3900	46°50′–47°	11°30′–40′E
35/41	ditto ditto ditto	ditto	ditto	ditto
36/17	Central Alps	—	46°–47°	7°–10°E
33/11	Austria	650–1650	46°–49°	10°–17°E
32/1010	Böhmerwald, Czechoslovakia	high	48½°–49½°	12½°–14°E
32/1012	Carpathian Mts., Czechoslovakia	3200–3300	48½°–49½°	17°–22°E
34/56	Valea Mare and Urbanistilor forests, Mt. Bihor, Rumania	3600–5600	46°19′–31′	22°41′–23°3′E
36/60	Rumania	—	—	—
	BEDGEBURY FOREST PLOTS			
29/527	Mandally Wood, Invergarry forest, Inverness-shire, Scotland*	200–500	57°4′	4°48′W
30/17	Rübeland State Forest, Harz Mts., Germany	1300–2300	51°44′	10°52′E
28/29	Lower Austria	—	48°49′	15°17′E

*Not native. Original provenance unknown.

DOUGLAS FIR SAMPLE PLOTS AT TORTWORTH, GLOUCESTERSHIRE

By J. M. CHRISTIE,
Mensuration Section

THE two Douglas fir sample plots at Tortworth, which are now (1954) 85 years and 71 years old respectively, have been under observation for forty years; they provide some useful information on the growth of Douglas fir above the age of most of the existing plantations of this species in Great Britain. Although the two plots are adjacent there have been marked contrasts in their development. Their growth from 1912 to 1951 is here discussed with reference to their differences and the possible causes of these.

The measurements in these plots have been made with the kind permission of the Tortworth Estates Company. The first ones were made in 1912, and were discussed in a paper by the late Lord Robinson (then Mr. R. L. Robinson) in the *Quarterly Journal of Forestry*, No. 8, 1914. A more detailed report by the same author (anonymously) was published in the same year in the *Journal of the Board of Agriculture*.

Situation

The plots are situated in Ironmill Grove, Tortworth, Gloucestershire. The wood is 18 miles north of Bath and 4½ miles east of the river Severn; it is on a fairly steep slope, 26° to 30°, on the southern bank of the Little Avon. The lowest point is 60 feet and the highest 90 feet above sea level. The aspect varies from north to north-east.

Plot E.19, near the river at the bottom of the slope, was planted in 1869 and is more sheltered than plot E.20, which is 50 yards away from the river and was planted in 1883. Both plots are exposed to west and north-west winds, but some shelter is afforded, by the hill behind them, against the prevailing south-west wind. Plot E.19 is, however, more sheltered than E.20.

The average annual rainfall is about 28 inches. Records for the nearest meteorological stations, at Quedgeley, south of Gloucester, and at Cheltenham, for the years 1881-1951, give average annual rainfall as being 27.90 and 26.47 inches respectively.

Geology and Soil

The geological formation is the Upper Llandovery Sandstone series of the Silurian. Soil pits dug in 1912 showed that the humus layer averaged 2 inches in depth, over 3 inches of brown loam, over a subsoil of reddish loamy clay mixed with pieces of micaceous and fossiliferous sandstone, reaching to a depth of at least 46 inches.

In 1951 the depth of the humus layer had increased to 4 inches in both plots. There followed a variable layer of brown clay-loam. In Plot E.19 the lower portion of this layer showed signs of gleying, and the subsoil was reached at 24 inches. In plot E.20 the subsoil was reached at 12 inches and there was no sign of gleying. In both plots roots of the crop were found up to 30 inches below the surface.

Between the years 1912 and 1951 the depth of soil which was stained by humus deposition had increased from 3 inches in both plots, to 24 inches in plot E.19 and to 12 inches in plot E.20.

Past History of the Wood

The land had previously carried a crop of rough hazel coppice with standards of oak and ash. This was clear felled and the land planted with Douglas fir. About an acre was so planted in 1869, and in 1883 a further 2¼ acres were planted. Early treatment in both sections appears to have been the same. The Douglas fir were planted at a distance of 12 to 15 feet apart, and the plants used were 3 to 4 feet high. The coppice was allowed to grow up with the Douglas fir and was cut about 1900, when it was big enough for pitwood. Other conifers in the wood when it was first measured in 1912 were *Cupressus macrocarpa*, Lawson's cypress and *Sequoia sempervirens*. All these were in the younger portion of the wood and two of the *Sequoia* trees were included within the area of plot E.20. In the younger stand a number of Lawson cypress remain on the upper edge of the crop and one *Sequoia sempervirens* now remains within plot E.20. There are no *Cupressus macrocarpa* remaining and the Lawson cypress are all of inferior growth to the Douglas fir. Some shelter is afforded to the Douglas fir in both plots by this belt of cypress and broadleaved trees at the top of the slope; in fact very few crowns of the Douglas fir are above this shelter; where the crowns do protrude they are severely damaged by wind. As shown in Photo 1 the crowns of the trees are more or less level, despite the slope of the ground. Plot E.19 is on the right-hand side of the photograph and plot E.20 is in the left centre.

The trees in the two plots appear to be of different "types" and in particular the appearance of the bark is most striking. In plot E.19 (see Photo. 3) the bark of the trees tends to be very finely fissured, while the bark of the trees in the plot E.20 (see Photo 2) is very rough and coarsely fissured.

Nothing is known of the seed origin of the plants; the difference in "type" may have contributed to the difference in vigour of the two plots, which has been remarked upon for over thirty years.

Records of Growth

In 1912 small sample plots were placed in both portions of the wood. The stocking in these plots was then complete, consistent with the wide initial spacing of about 14 feet, and there had been no thinning beyond the removal of the coppice.

In 1919 the plots were adjusted to their present boundaries. The present size of the plots is larger than in 1912, and the subsequent measurements are therefore not entirely comparable with those then made. Since 1919 both plots have been thinned to a B grade, which is a light low thinning in which the trees removed are, in the main, only suppressed ones. Further measurements and thinnings took place in 1924, 1929, 1934, 1941 and 1951. Table 46 gives details of the 1912, 1919, 1934 and 1951 measurements. In subsequent tables only data from the 1919, 1934 and 1951 measurements are quoted, so that the rate of growth compared in these tables is based on a comparable sample area.

In Table 46 the data for the 1912 measurement are given in italics. The data for E.19 are from one small sample plot 0.13 acres in area while that for E.20 is based on the average from two plots, 0.09 and 0.10 acres respectively. The present size of the sample plots is E.19:0.230 acres and E.20:0.355 acres. In E.19 the resited plot included seven more trees per acre than the original plot; and in plot E.20 there were fourteen trees per acre less than in the original plot. These

Table 46

RECORD OF PERIODICAL MEASUREMENTS PER ACRE IN TWO DOUGLAS FIR SAMPLE PLOTS

Year of measurement	Age of crop	Main Crop							Intermediate Yield from Thinnings		Total Crop Yield to Date		Periodic Annual Increment	
		Number of trees per acre after thinning	Height: Average of 100 largest trees	Height: Average of crop	Form Factor	Quarter Girth at 4ft. 3in.	Basal Area per acre after thinning Q.G.	Vol. per acre (over bark) Q.G.	Number of trees	Vol. per acre (over bark) Q.G.	Basal area Q.G.	Vol. (over bark) Q.G.	Basal Area Q.G.	Vol. (over bark) Q.G.
	Years		Feet	Feet		Inches	sq. ft.	cu. ft.		cu. ft.	sq. ft.	cu. ft.	sq. ft.	cu. ft.
						E.19 (Quality Class I in 1951)								
1912	*43*	*215*	*(97½)*	*94*	*.365*	*12*	*211.1*	*7338*	—	—	*211.1*	*7338*	—	—
1919	50	196	109½	106	.375	12½	215.3	8560	26	348	226.9	8908	—	—
1934	65	174	121½	119½	.362	13¾	229.9	9931	22	562	257.7	10841	2.1	129
1951	82	157	130	125½	.396	14½	227.9	11014	17	935	277.3	12859	1.2	119
						E.20 (Quality Class III in 1951)								
1912	*29*	*205*	*(69½)*	*66*	*.442*	*9¾*	*137.5*	*4300*	—	—	*137.5*	*4300*	—	—
1919	36	177	81½	78½	.397	10¼	126.7	3941	14	50	130.2	3991	—	—
1934	51	160	98	94½	.399	11¾	154.7	5851	17	140	164.1	6041	2.3	137
1951	68	118	104½	104	.401	13¼	144.9	6042	42	941	181.0	7173	1.0	67

Notes: Figures in brackets are estimated.
The 1912 data, given in italics, are from a smaller sample area than subsequent measurements.

differences in stocking mean that, compared with subsequent measurements, the figures for 1912 in plot E.19 are low whereas those for E.20 are high. This is particularly noticeable in the case of E.20 where there is an apparent drop in both total volume and total basal area production between 1912 and 1919.

Height Growth

Plot E.19 has always been of Quality Class I according to the revised yield tables for conifers (Forestry Commission 1953), while E.20 is now only of Quality Class III, although to 51 years it was Quality Class II. This plot seems to be less vigorous than plot E.19; this may be attributed partly to exposure, because as early as 1924 the crowns of the trees in the upper portion of plot E.20 showed distinct signs of wind effects. Also, plot E.20 is further away from the

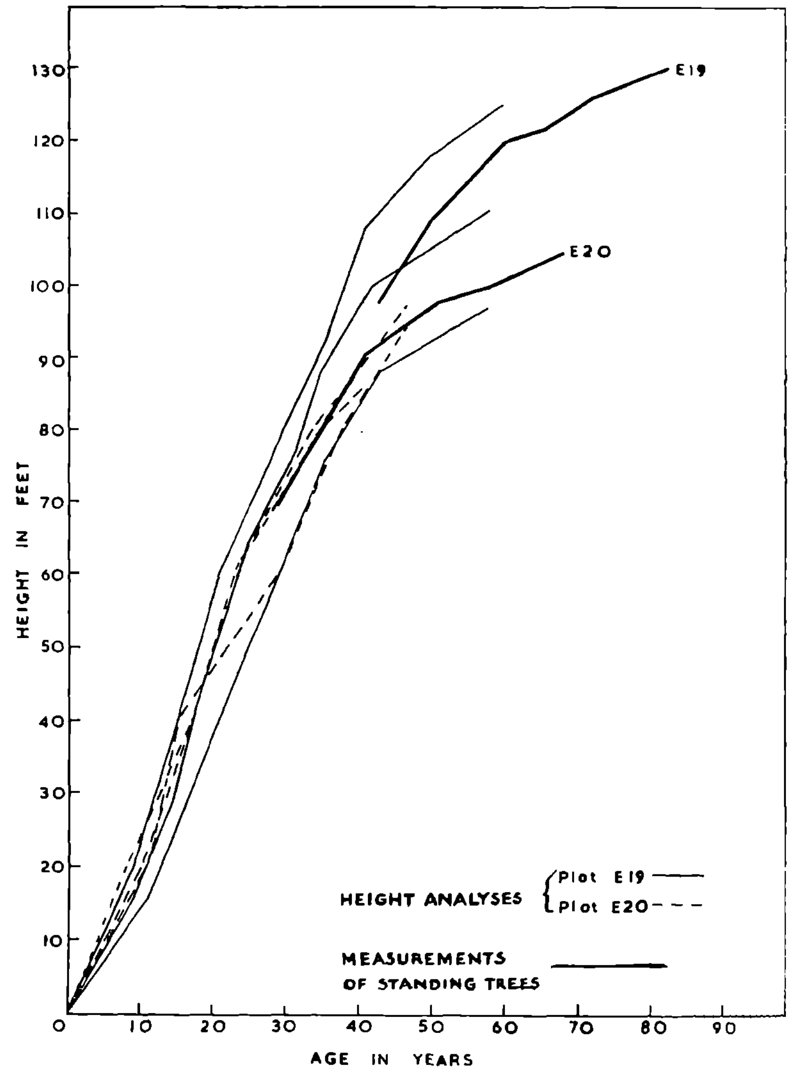


Fig. 14. Height development in sample plots E19 and E20 derived from stem analyses of blown trees and from measurements of standing trees.

river and the depth of soil is less than in plot E.19. Between the ages of 50 and 65 years the top height of E.19 increased by 12 feet, while between 51 and 68 years E.20 only grew 6½ feet.

Figure 14 shows the development in height growth in the two plots. The heavy lines on this graph show the top height development since measurements began, top height being defined as the average height of the 100 largest girthed trees per acre.

The height growth before 1912 has been obtained by stem analyses of windblown trees. It appears that up to 40 years of age the height growth in both plots was very similar. Beyond this age, height growth has fallen off rapidly in plot E.20; but it is not until 60 years that there is any tendency in plot E.19 for height growth to slow down. This suggests that it is not any inherent lack of vigour, but rather the exposure of plot E.20, and possibly the shallower soil, that has caused growth to slow down after only 40 years.

In plot E.19 the minimum and maximum heights measured in 1912 (43 years) were 81½ and 106 feet, by 1951 the minimum and maximum heights measured in this sample plot were 97 and 143 feet. In plot E.20 the minimum height measured in 1912 (29 years) was 60½ feet and the maximum height was 80½ feet. In 1951 the corresponding heights were 86½ feet and 123½ feet. In both cases the 1912 figures refer to the wood as a whole while the 1951 figures refer only to the sample areas.

Girth Increment

Table 47 gives the girth range and mean girth for the 100 largest trees per acre (the dominant trees) and for the plots as a whole, in the years 1919, 1934 and 1951.

In plot E.19, the increase in the average girth of the 100 largest trees per acre was 5 inches for the 15-year period 1919 to 1934, and 2 inches for the 17-year period 1934 to 1951. These increases in girth correspond to an annual increase of 0.33 inches for the first period, and 0.12 inches for the second; the corresponding average ring widths are approximately 1/20th and 1/50th of an inch respectively. In plot E.20 the increase in the average girth of the 100 largest trees per acre was 6½ inches and 2½ inches for these periods. This is equivalent to average ring widths of 1/17th and 1/50th of an inch. The drop in girth increment in both plots during the second period is partially due to age and partially to the very light thinning treatment. If the intensity of thinning had been increased the girth increment would probably have been greater. A rather different result would be obtained if the mean girths in the plots were compared instead of the girths of the 100 largest trees per acre, because in E.20 a large number of the smaller trees in the plot have been removed in thinnings, while in plot E.19 the thinnings have not been entirely restricted to the smaller girth classes, because of the incidence of windblow. The presence of the smaller trees in plot E.19 has depressed the average girth of the plot.

In plot E.19 the largest tree in the plot has increased its girth by 17½ inches in 32 years, an average of about ½ inch a year; in E.20 over the same period the largest tree has averaged about ⅓ inch a year corresponding to an increase in girth of 11½ inches.

Volume and Increment

Table 46 gives the comparative yields per acre in these plots for the years 1912, 1919, 1934 and 1951, and also the periodic annual increments. At 50 years the standing volume per acre in plot E.19 is 8,560 hoppus feet over bark. This is

Table 47

GIRTH DEVELOPMENT 1919 TO 1951 OF TWO DOUGLAS FIR SAMPLE PLOTS

Plot Number			Year of Measurement			Period of Measurement			
			Girth (inches)			Average girth increment for Period (inches)		Average girth increment per year (inches)	
			1919	1934	1951	1919-1934	1934-1951	1919-1934	1934-1951
E.19	100 largest trees per acre.	Girth range	68–49½	78–51½	85½–51½	5	2	0.33	0.12
		Mean girth	56½	61½	63½				
	All trees in plot	Girth range	68–36	78–36½	85½–37½	4½	3	0.30	0.18
		Mean girth	50½	55	58				
E.20	100 largest trees per acre.	Girth range	60–38	67–41½	71½–41½	6½	2½	0.43	0.15
		Mean girth	46	52½	55				
	All trees in plot.	Girth range	60–19½	67–28	71½–36½	6½	6	0.43	0.35
		Mean girth	40½	47	53				

more than 1,000 hoppus feet per acre greater than the volume for Quality Class I shown in the Forestry Commission Yield Tables; and this is due to the plot's heavier stocking. The average volume per tree in the plot is 44 hoppus feet, while the corresponding volume in the yield tables is 58 hoppus feet. The volume of 5,851 hoppus feet over bark per acre in plot E.20 at 51 years is less than that shown in the yield tables for Quality Class II Douglas fir, which is the Quality Class of plot E.20 at this age, although there are more stems per acre. The fact that the average volume per tree in plot E.19 is lower than that given in the yield tables, and that the volume per acre of the main crop in plot E.20 is less than is given in the yield tables, can be attributed to two main causes, The first is that both plots have only been thinned lightly since canopy formed, and therefore the trees have a comparatively small girth for their height; the second that the form factors at 50 years in both plots are low compared with those given in the yield tables. The form factor in E.19 is 0.375 and that in E.20 is 0.399, compared with form factors of 0.42 and 0.43 for the respective quality classes in the yield tables. It may have been the wide initial spacing that has caused the trees to have a fairly pronounced taper.

Between 50 and 82 years the volume per acre of the main crop in E.19 increased by 2,454 hoppus feet to 11,014 hoppus feet. The main crop volume in plot E.20, between 51 and 68 years, increased by only 191 hoppus feet, but in this period 941 hoppus feet were removed in thinnings.

In Table 48 the distribution of the numbers of stems, the standing volumes per acre and the yield from thinnings are given by quarter girth classes for the years 1919, 1934 and 1951.

Because of the differences in stocking, and the fact that the two plots are of different quality classes, it is, however, more instructive to compare the proportion of the volume in each girth class instead of the actual volumes. The volumes of thinnings refer only to Douglas fir, as no data were available for the volume of coppice removed from the plots.

In plot E.19 more than half of the standing volume was in the 12¼-15 inch quarter girth class in 1919, when the age was 50 years, and 15 per cent, of the volume was in the 15¼ inch and above q.g. class. By 1934, 49 per cent, of the volume was in the 12¼-15 inch q.g. class, and the proportion of the volume in the upper q.g. class had risen to 37 per cent. In 1951 only 7 per cent of the volume remained in the 9¼-12 inch q.g. class, the remainder of the standing volume being almost equally divided between the upper two q.g. classes shown in the table. The distribution of the volume in plot E.20 is similar at a given age to that found in plot E.19. In 1919, at 36 years of age, 55 per cent, of the volume is in the 9¼-12 inch q.g. class. In 1934 at 51 years of age the distribution of the volume is similar to that in plot E.19 at 50 years, again at 68 years the volume distribution in E.20 corresponds to that in E.19 at 65 years.

The volume of thinnings per acre removed between 1919 and 1951 is low in both plots. No thinnings were removed prior to 1919. This low volume of thinnings is partly due to the B grade of thinning applied to both plots in which only suppressed and subdominant trees are removed, and partly to the wide initial spacing as a result of which there were no early thinning yields. Table 48 shows that 680 hoppus feet per acre have been removed from plot E.19 in the 15¼ inch and over quarter-girth class. This is over one third of the total volume removed, and is due to the removal of blown trees, otherwise trees removed in this plot and in plot E.20 have been mainly suppressed trees in accordance with the grade of thinning applied.

Table 48

DISTRIBUTION OF NUMBER OF STEMS AND VOLUMES PER ACRE BY GIRTH CLASSES IN TWO DOUGLAS FIR SAMPLE PLOTS

Quarter Girth Class (inches)	1919			1934			1951			Volume per Acre Thinnings 1919-1951 Hoppus ft.o.b.	Total Volume Production 1912-1951 Hoppus ft.o.b.
	No. Stems per acre	Volume per acre Hoppus ft.o.b.	% Volume	No. Stems per acre	Volume per acre Hoppus ft.o.b.	% Volume	No. Stems per acre	Volume per acre Hoppus ft.o.b.	% Volume		
Plot E.19											
Up to 6	—	—	—	—	—	—	—	—	—	—	—
6¼–9	4	90	1	—	—	—	—	—	—	260	260
9¼–12	79	2330	27	43	1410	14	26	820	7	740	1560
12¼–15	96	4900	57	87	4830	49	83	5160	47	170	5330
15¼ and over	17	1240	15	44	3690	37	48	5030	46	680	5710
Total	196	8560	100	174	9930	100	157	11010	100	1850	12860
Plot E.20											
Up to 6	8	40	1	—	—	—	—	—	—	50	50
6¼–9	54	620	16	31	470	8	—	—	—	450	450
9¼–12	87	2160	55	56	1480	25	42	1170	19	470	1640
12¼–15	28	1120	28	62	3010	52	48	2580	43	160	2740
15¼ and over	—	—	—	11	890	15	28	2290	38	—	2290
Total	177	3940	100	160	5850	100	118	6040	100	1130	7170

Total production up to 1919 was much lower in both plots than that given in the Yield Tables for the age and site quality. In plot E.19 total production was 8,908 hoppus feet per acre compared with the yield table figure of 10,700 hoppus feet per acre. In plot E.20 the equivalent volumes were 3,991 and 7,340 hoppus feet per acre. This comparatively low total production in the two plots must largely be attributed to the wide initial spacing as a result of which there were no early thinning yields. Stocking in the two plots at 50 years was however complete, and in fact higher than is shown in the yield tables; beyond this age no comparison with the yield tables is possible because they only extend to 50 years.

From Table 46 it will be seen that the periodic annual volume increment in plot E.19 was 129 hoppus feet over bark per acre between 50 and 65 years. This increment is almost double that in plot E.20 for the comparable period, 51 to 68 years, where the annual volume increment was 67 hoppus feet over bark per acre. In plot E.19 there has been only a slight drop in periodic annual increment while in plot E.20 it fell sharply. The periodic annual basal area increment in plot E.19 is also double that in plot E.20 for the comparable period.

Between 65 and 82 years the annual volume increment in plot E.19 averaged 119 hoppus feet, although the average ring width of the 100 largest trees during this period was only 1/50th of an inch. The reason why such narrow rings resulted in this comparatively large volume increment is that the rings, although narrow, were put on to a very big surface: the trees were large in girth, very tall, and the stocking was dense. This is a good, if perhaps extreme, illustration of the insufficiently heeded fact that narrow rings are not necessarily an indication of low volume increment per acre.

Conclusions

The study of these two crops on adjacent sites indicate to some extent how much the factors of environment and possibly provenance influence the growth of a species. Plot E.19 being on a slightly more favourable site shows the potentialities of a good strain of Douglas fir grown in favourable situations. The annual increment of this plot at over 80 years is still more than 100 hoppus feet per acre. The poorer growth and form and the coarser branching of the adjacent plot E.20 have been remarked upon by various people for over 30 years.

The evidence suggests that differences in seed origin, in fertility of site and exposure are the main factors responsible for the marked difference in development between the two crops, and of these factors it seems that the most important one has been exposure.

REFERENCES

ANON. (1914) Some Douglas fir plantations IV—Tortworth Wood, Gloucestershire. *Journal of the Board of Agriculture.* Vol. XX, No. 10 (January, 1914), 865-875.

HUMMEL, F. C. and CHRISTIE, J. (1953) *Revised Yield Tables for Conifers in Great Britain.* Forestry Commission. Forest Record No. 24.

ROBINSON, R. L. (1914) Some Douglas fir plantations. *Quarterly Journal of Forestry*, 8 (1914), 187-190.

CHANGES IN THE CHARACTER OF THE WOODLAND OF A RECENTLY SURVEYED COUNTY

By G. M. L. LOCKE,
Census Officer

A complete area survey of all the woodlands in Great Britain of five acres and over in extent took place between 1947 and 1949. (1, 2.) It was the most complete survey of its kind ever carried out here, and so will provide a sound basis for comparison in future years. A revision of this Census was started in 1953, its main purpose being to find out the changes which are taking place in the woodlands of Britain and the rate at which these changes are occurring. This survey is being carried out by a process of continuous revision, whereby a number of counties are resurveyed each year. The complete resurvey of the country will take between twelve and fifteen years. The first year's work in England was confined to some of the smaller counties, so that any difficulties encountered during the survey could be resolved while the work was still confined to a limited area. The definitions of type and age class have been kept essentially the same as those of the 1947 Census, so that valid comparisons may be drawn.

This article will show the present character of the woodland in the county of Huntingdon, which was the second county in England to be surveyed, and also some of the changes which have taken place within the last thirty years.

Huntingdonshire has a land area of 234,000 acres and is the fourth smallest county in England. The topography of the county is undulating but there is a definite slope from the higher ground in the West, where the highest point is just over 250 feet, to the fen area in the east, where the ground is practically at sea level. The solid geology is of the Jurassic period and is composed mainly of the Oxford clay and Kellaway beds dipping gently to the south-east; this formation is, however, largely overlain with glacial and post-glacial deposits. The soils in the western regions of the county tend to be heavy and of rather low quality, whilst the Fen soils of the east are famed for their high agricultural productivity. The main occupation within the county is agriculture and more than half the area is utilised as arable land. The digging of clay for brickworks, and the working of gravel, are locally important and have led to some loss of woodland in recent years. Woodland industries are few and the growing of timber has been confined mainly to producing material for local estate and farm maintenance work.

Very little information can be obtained on the area and type of woodland present in the years prior to the 20th century. The evidence of "bog oak" occurring in the Fens show that this area, at least, must have been fairly extensively wooded in early times, and it may be surmised that the western upland areas were equally so. One of the first definite estimates of woodland acreage was that of the Board of Agriculture which quotes a figure of 5,000 acres in 1913. In 1924 the Forestry Commission carried out a Census of Woodlands based on returns from landowners, and the Report (1) gives the area as 4,525 acres in woods of over two acres in extent; or a percentage woodland area of 1.9, a very low figure compared with the average, for Great Britain, of 5.3. Although the Board of Agriculture return of 1913 was an estimate, it is quite probable that there had been some reduction in woodland area due to some of the areas clear felled during the 1914-1918 war being converted to other types of land use. The Land Utilisation survey of 1932 quotes a figure of 4,500 acres, but this figure was based on the 1924 Census.

In 1942 the Home Timber Production Department made an estimate of the woodland area in the county by means of an ingenious method of using intercepts on one-inch maps. Their estimate of the woodland acreage was 6,200 acres, a total far in excess of the previous figures. The 1942 survey was, of course, a sample survey, but the results were shown to be reasonably accurate by the 100 per cent area survey made by the Forestry Commission in 1947, which showed that the area of woodlands of five acres and over in extent was 5,902 acres.

The Census revision of the county made in 1953 covered all woodlands of one acre and over in extent, but in order that the figures may be compared with those of 1947, the figure used here is that obtained for woods of five acres and over. This area of 6,250 acres is greater than that obtained in 1947, and shows an apparent increase of almost 350 acres during the intervening six year period. This increase can be explained in several ways. Firstly, many of the six-inch Ordnance Survey maps used had recently been brought up to date, and areas were marked as woodland which had been shown as bare, or only sparsely covered with trees, on the older edition of the maps; some of these areas were consequently missed, despite all the precautions taken, on the 1947 survey. Secondly, extensions to blocks of woodland previously under five acres in extent were often sufficient to bring them to an acreage exceeding five acres; as all woods under five acres in extent were ignored in the 1947 survey, this change of status was therefore often unseen. Thirdly, some areas which were omitted from the 1947 Census on the grounds of insufficient stocking were included in the 1953 Census as being just sufficiently stocked to justify their inclusion. Finally, some new woods may in fact have been planted, but little evidence of this was encountered.

It is difficult to correlate these returns precisely because of the different bases on which they have been constructed. Some of the reasons are given above, and another is that for the three surveys carried out by the Forestry Commission three different minimum acreage limits, each appropriate for its immediate purpose, were laid down. It is possible to compare the 1947 and 1953 surveys directly due to the computational methods adopted in the latter survey, but it is not possible to compare the surveys of 1924 (woods over two acres in extent) and 1947 (woods five acres and over in extent) in a similar fashion. However, it would appear from the figures available that the woodland acreage, apart from a reduction during the 1914-18 war and for possibly a few years thereafter, has increased since 1913.

A comparison of the constitution of the woodlands by type, for the three Forestry Commission surveys of 1924, 1947 and 1953, is given in Table 49.

One significant point in the 1924 Census figures is the large area classed as uneconomic. Uneconomic was then defined as areas which are not maintained for timber production but primarily serve some other purpose e.g. amenity woods, shelter belts, etc.This area of 1,043 acres represents nearly one-quarter of the total woodland acreage in the county. In subsequent surveys the term uneconomic was dispensed with, and amenity areas and shelter belts were classified under their main type.

COMPARISON OF THE WOODLANDS OF HUNTINGDONSHIRE AT THREE DIFFERENT DATES

Table 49

Species	1924 Census +		1947 Census*		1953 Census*	
	Area	Per cent of Total	Area	Per cent of Total	Area	Per cent of Total
Coniferous High Forest	329	7	39	1	69	1
Mixed High Forest	205	5	127	2	89	1
Broadleaved High forest	868	19	1959	33	2967	48
Coppice with Standards	1598	35	991	17	972	16
Simple Coppice	37	1	684	11	704	11
Scrub	52	1	1402	24	1275	21
Devastated	393	9	166	3	31	—
Felled			534	9	143	2
Uneconomic	1043	23	—	—	—	—
Total	4525	100	5902	100	6250	100

+ = woods of 2 acres in extent and over.
* = woods of 5 acres in extent and over.

One interesting point brought out in Table 49 is the decline in acreage of both Coniferous and Mixed High Forest. Coniferous High Forest has declined from 329 acres in 1924 to 39 acres in 1947; although the figure now appears to be rising it represented only 1 per cent of the woodland area in 1953 as against 7 per cent in 1924. Mixed High Forest has declined from 205 acres in 1924 to 127 acres in 1947, and the 1953 resurvey shows that the area under this type is still diminishing. Broadleaved High Forest on the other hand increased from only 868 acres in 1924 to nearly two thousand acres in 1947 and to nearly three thousand acres in 1953. The increase in the last six years can be partly attributed to the areas that escaped inclusion in the survey of 1947, for reasons given above, and partly from a more detailed classification of some of the areas covered by the 1947 survey. The greater intensity of survey in the Census revision, and the consequently smaller stands, have led to small patches of high forest being classified separately and not included in a larger area of different type, as sometimes occurred in the 1947 survey when differentiation of these small areas was not always made. It must also not be forgotten in comparing the 1924 and 1947 surveys that the figure quoted in 1924 is probably an underestimate, since a considerable acreage in the uneconomic class is probably amenity woodland with a high percentage of Broadleaved High Forest.

It would appear, however, that although Coniferous and Mixed High Forest have declined, the total area of High Forest itself has now increased, and that in this county broadleaved species are now more prevalent in this class than at any time during the last thirty years. This remarkable increase in the area under Broadleaved High Forest calls for some discussion, especially as there is little evidence of the large-scale planting of broadleaved trees. It is apparent that many stands recorded in the two earlier surveys as Mixed High Forest, Coppice with Standards, or Scrub, have subsequently developed to the point where the description of Broadleaved High Forest was the appropriate one. To some extent these changes are masked in the figures given in Table 49, owing to other developments going on at the same time. For example, much of the 1,402 acres recorded as Scrub in 1947, had progressed to High Forest by 1953; and the 1,275 acres classed as Scrub in 1953, included much ground which was recorded as Felled or Devastated in 1947.

Although Coppice-with-Standards has declined in area since 1924, the area of Simple Coppice has increased by a similar amount, showing that considerable areas of standards over coppice have been felled, thus converting the area to Simple Coppice. The coppice industry in this county, however, appears to have declined over a long period of years, and from the results of the 1953 survey, only about 50 per cent of the area under coppice under standards, and less than 10 per cent of the area under Simple Coppice, appears to be worked on rotation, although a considerable acreage of the remaining coppice is probably worked sporadically.

Scrub woodland amounted to only 52 acres in 1924, but by 1947 the area had increased to 1,402 acres; although this area had been reduced to 1,275 acres in 1953, the type still occupies over one fifth of the woodland area. Over one third of the area in this category in 1953 occurred in one block at Wood Walton Fen, and it is probable that in 1924 this area was not classed as woodland. The area of Devastated and Felled woodland showed an increase from 393 acres in 1924 to 700 acres, in 1947, mainly as a result of war-time fellings. By 1953 the area had been reduced very considerably, partly by planting, partly by reclassification of the stands, whereby sparsely stocked areas were moved to another category, and partly by natural succession to Scrub, Coppice or High Forest. (See Table 50.)

AGE CLASS DISTRIBUTION OF HIGH FOREST IN HUNTINGDONSHIRE

Table 50

Year of Survey	1-10 years	11-20 years	21-40 years	41-80 years	Over 80 years	Uneven	Total
1924	—	1%	25%	69%	5%	—	100%
1947	2%	9%	14%	14%	19%	42%	100%
1953	3%	3%	9%	19%	14%	52%	100%

In 1924 all the High Forest was placed in definite age-classes, and where uneven-aged woodlands occurred the stand was assigned to the age-class which predominated. In both the 1947 and 1953 surveys a special uneven-aged age group was created to cover areas of this type. There is thus again no direct comparison between the results. However, several significant points arise from Table 50. Firstly, in 1924, the absence of any appreciable woodland area in the 1-10 year age-class. This shows that despite the fellings which had taken place in the older crops, there had been no attempt to counterbalance these losses by means of planting or replanting, either during the 1914-18 war or in the immediate post-war years. Secondly, almost 70 per cent of the High Forest area occurred in the 41-80-year age-class, and only 5 per cent occurred in the over-80-year age-class. The results of the 1947 survey show that war fellings had been offset to some extent by planting, although the planted area concerned can bear little relation to the area that must have been clear-felled. The acreage in the 81-years-and-over age-class had increased from 5 per cent in 1924 to 19 per cent in 1947, and the bulk of this area has come from the immature crops spared in the 1914-18 war. By 1953 the area in the 1-10-year age-class had increased to 3 per cent of the High Forest area, most of the area being under broadleaved species.

Uneven-aged woodland constitutes an important factor in the High Forest area of the county. In 1947 this class occupied over 40 per cent of the area, and by 1953 the figure had risen to over 50 per cent. In the 1947 Census uneven-aged crops were not further subdivided in a manner which enabled us to easily ascertain the age range present. In the 1953 Census Revision, however, the uneven-aged High Forest was divided into three classes, (1) Mainly 1-60 years (2) Mainly over 60 years, and (3) All or most age-classes present; the results showed that the uneven-aged woodland in the county occurred in the proportion of 1:1:2 for these three classes.

The 1924 Census unfortunately gave no information on the main species which were present in High Forest at that time, and the changes in the distribution of species in the last thirty years cannot therefore be followed. The results obtained in the 1953 survey give us the present structure. Oak with 41 per cent is by far the most common species, and occupies most of the area in the uneven-aged and the older even-aged age-classes. Other important species are birch with 21 per cent, ash with 18 per cent and elm with 13 per cent. These four species between them therefore account for 93 per cent of the High Forest area. Of the Coniferous species only Scots pine and Norway spruce are individually important and then only to the extent of about one per cent each.

An examination of the records for individual stands that were surveyed both in 1947 and 1953, revealed that changes in their classification had often been found appropriate. These changes followed no simple pattern.

Woodlands Lost to Other Forms of Land Use

In the 1947 survey, a record was made of the woodland areas lost to agriculture or other forms of land use. These were found to amount to 70 acres, equivalent to 1 per cent of the area surveyed (existing woodland + lost woodland); this was the lowest area noted in any English county.

Unfortunately it cannot be related to any precise span of years, as it is based on differences between the use of the ground at the date of survey, and that shown on Ordnance maps revised at various dates from 1902 to 1928. Nevertheless, the conclusion may be drawn that over the period 1902 to 1947 there was little conversion of woodland to other uses in Huntingdonshire.

Of the woodland in blocks of five acres and over surveyed in 1947 approximately 90 acres had been lost by 1953. The rate of conversion of woodland areas to other types of land use had therefore increased between 1947 and 1953 and the area converted during this period was considerably greater than the area converted during the previous twenty years.

Small Woods of One to Five Acres

The one-to-five-acre woods were never completely surveyed as a separate group until 1953, as woods of two acres and under in extent were excluded from the 1924 Census and woods under five acres from the 1947 Census. In 1951 a country-wide sampling survey (4) was carried out to obtain information on the type and age-class structure of these woods. The sampling fraction used was too small, however, to give reliable estimates for a single county, although adequate to give an estimate for the country as a whole. Further information on these "small woods", as they were termed, was considered desirable, and consequently in the 1953 Census revision it was decided to survey all woods of one acre and over. In Huntingdon these woods cover an area of 412 acres, or about 6.5 per cent of the area of woods of 5 acres and over in extent. It is probable that at one time they accounted for a larger area than they do now, and that claims of agriculture have been the main factor in reducing their area.

The type distribution is unlike that of the woods of 5 acres and over in extent. 332 acres, or 81 per cent, is Broadleaved High Forest; Coniferous and Mixed High Forest are of only minor importance as was the case in large woods.

Six per cent of the area is under coppice types and nine per cent is classed as unproductive woodland. The one-to-five-acre woods therefore appear to have largely escaped the fellings carried out in 1939-45 war, and this assumption is largely borne out by the age-class structure of these woods, inasmuch as more than half the High Forest area is over 40 years of age, compared with only one third in the woods of five acres and over.

Hedgerow and Park Trees

A Hedgerow Survey, to calculate the volume of timber in Hedgerow and Park trees and in woods under one acre, had never before been done on a county basis. Estimates of the volume in this class of timber were made in 1939, 1942 and 1951, for the country as a whole and for certain major regions (4); but the sampling fractions have always been too low to give reliable figures for a single county, or even for a small group of counties. In the Census Revision in 1953 it was decided to increase the sampling fraction to a point where tentative county estimates could be made.

The method used for obtaining the volume estimates was not materially altered from the two previous surveys. All timber trees, either isolated or in groups under one acre in extent, which occur on randomly selected strips, were measured for girth and height. These strips were one mile long and two chains wide, covering an area of 16 acres, and the number of strips to be measured in any one county depended on the number of six-inch Ordnance Survey maps covering that county. In Huntingdon the number of strips actually measured was 21, covering an area of 336 acres, or 0.14 per cent of the land and inland water area of the county (234,000 acres).

The distribution of hedgerow trees does not always conform to the distribution of woodland. In any one region the character of the woods and their disposition may not vary greatly, and there is often a more or less set pattern of farm and forest. Hedgerow trees, arising as they normally do from natural means, do not conform to any pattern, and there is often quite a change in species, and in the number and size of the trees, over quite short distances. In addition to this, the type of land use has a big effect on distribution. In Huntingdon, which is a predominantly agricultural county, the distribution of hedgerow timber varies according to the type of farming practised. In the west and south of the county hedgerow trees are fairly numerous. In the Fen area, however, trees are now almost non-existent and this fact is primarily due to two reasons; firstly, the productivity of the soils is very dependent on drainage and the presence of trees along the ditches, which form the main field boundaries in the region, might interfere with drains or with cleaning operations; secondly, the productivity of the soil is so great, and the value so high, that farmers consider that the presence of trees interferes with the very intensive farming methods practised on these fertile soils.

Table 51 gives the estimated volume of hedgerow and park timber in the county by species and girth classes.

When the total volume of 11.3 million hoppus feet is compared with the total land area of the county, it gives a figure of 48.4 hoppus feet per acre. This figure is almost two-and-a-half times that of the figure obtained for the East England Conservancy as a whole in the Hedgerow Survey of 1951, but it must be remembered that the latter figure is an average one for an area of 8 million acres. Nevertheless, for a county with so much fenland the Huntingdon figure appears remarkably high.

VOLUME OF TIMBER IN THE HEDGEROW AND PARK TREES OF HUNTINGDONSHIRE, 1953

Table 51 Thousands of hoppus feet, over bark

Species or Species Group	°Saplings 6 inches girth & under	†Timber Quarter girth class, in inches: 6¼ to 9	9¼ to 12	12¼ to 15	15¼ to 18	18¼ to 21	21¼ to 24	24¼ & over	*Short Timber	Total	Percentage of Total Volume
Scots pine	—	8	5	—	—	—	—	—	—	13	—
Other Conifers	1	—	—	99	—	—	—	—	—	100	1
Total Conifer	1	8	5	99	—	—	—	—	—	113	1
Oak	—	3	19	29	79	43	146	924	30	1273	11
Ash	68	48	40	117	1231	33	237	706	25	1397	12
Beech	1	—	—	—	—	—	55	—	—	56	1
Birch	—	2	—	—	—	—	—	—	—	2	—
Sycamore	—	—	—	—	—	28	—	—	—	28	—
Elm	78	278	728	880	483	709	812	3045	13	7026	62
Other Broad-leaved	16	15	29	216	167	227	128	265	366	1429	13
Total Broadleaved	163	346	816	1242	815	1040	1378	4940	434	11211	99
Grand Total	164	354	821	1341	852	1040	1378	4940	434	11324	100
Percentage in each girth class	1	3	7	12	8	9	12	44	4	100	—

Notes: †Timber comprises trees, with a stem length of 10 feet, or over and a breast height quarter girth of 6¼ inches or over.

*Short timber comprises trees with a stem length between 6 and 10 feet, and a breast height quarter girth of at least 8 inches.

°Saplings are trees with at least 10 feet of straight stem, and between 2½ and 6 inches quarter-girth.

Huntingdon has long been famous for its elm and it will be seen from Table 51 that it is as isolated trees and as small blocks that this species reaches its greatest importance. Elm was fourth in importance on an area basis in the High Forest category of the Large Woods, first in importance on an area basis in the High Forest category of the Small Woods, and first in importance on a volume basis in Hedgerow and Park timber. Of the other Hedgerow and Park species only oak and ash are of individual importance.

From the girth-class distribution it will be seen that no less than 44 per cent of the total volume is in the largest size class, and that 85 per cent of the volume is in trees of over 12 inches quarter girth. The "short timber" category, i.e. trees with a breast height quarter girth of 8 inches or over whose stem length is between 6 and 10 feet, exhibits the same characteristics; the analysis of these trees shows that over 75 per cent of the volume is in stems of over 18 inches quarter girth.

From the sampling method adopted in this survey it is also possible to estimate the number of Hedgerow and Park trees in the county by species and girth classes as shown in Table 52. The total number of trees is estimated to be 411,000.

ESTIMATED NUMBER OF HEDGEROW AND PARK TREES IN HUNTINGDONSHIRE, 1953

Table 52 Thousands of Trees

Species or Species Group	Saplings 6 inches girth & under	Timber Trees — Quarter girth class in inches: 6¼ to 9	9¼ to 12	12¼ to 15	15¼ to 18	18¼ to 24	21¼ to 24	24¼ & over	Short Timber	Total	Percentage of Total number
Scots pine	—	—	1	—	—	—	—	—	—	2	—
Other Conifers	4	—	—	3	—	—	—	—	—	7	2
Total Conifer	4	1	1	3	—	—	—	—	—	9	2
Oak	1	1	2	1	2	1	9	2	2	22	6
Ash	54	10	3	6	4	1	7	2	2	91	22
Beech	1	—	—	—	—	—	—	—	—	2	—
Birch	—	1	—	—	—	—	—	—	—	1	—
Sycamore	—	—	—	—	—	1	—	—	—	1	—
Elm	43	45	46	33	12	12	23	1	1	227	56
Other Broad-leaved	8	3	3	11	6	5	4	15	15	58	14
Total Broad-leaved	107	60	54	51	24	20	43	20	20	402	98
Grand Total	111	61	55	54	24	20	43	20	20	411	100
Percentage in each girth class	27	15	13	13	6	5	10	5	5	100	—

Note: For definitions of saplings, timber trees, and short timber, see Table 51.

There are on average only two hedgerow trees per acre of land area, and the average volume per tree is about 28 hoppus feet. It would appear, therefore, that many of the trees are mature or overmature. Although 27 per cent of the number of trees is in the smallest size class, it is doubtful whether a sufficient number will reach maturity to maintain the volume at its present level. Many of the trees in the smallest size class have arisen from sucker shoots, and while those of the elm have generally satisfactory stem form, those of the other species tend to be poor and unlikely to produce timber of the present quality.

There has been considerable felling of hedgerow trees in this county for some years; but there was little obvious sign of the replanting of hedgerow trees to replace those that have been felled.

Ownership of Woodlands

During the 1953 survey details of ownership were taken wherever possible for woods of one acre in extent and over. Ownership was established for an area of 6,344 acres or 96 per cent of the surveyed private woodland area, and the number of owners concerned was 124. Ten owners with woodland estates of over 250 acres control almost 65 per cent of the woodland in the county. On the other hand over one third of the owners, many of them farmers, have woodland estates of 5 acres or less, involving an area which is only 2 per cent of the woodland total.

Summary

Huntingdon is not a well wooded county. The woodland acreage is apparently increasing, but in 1953 it still only represented 2.9 per cent of the land area of the county. In the large woods of five acres or over in extent, half the woodland area is High Forest, the majority being under crops of broadleaved species; one quarter is composed of coppice types and one quarter is unproductive.

Small woods of one to five acres in extent represent 6.5 per cent of the area of the larger woods. 85 per cent of the area of these Small Woods is under High Forest, again mainly under broadleaved crops, and only 9 per cent was classed as unproductive.

The volume in Hedgerow and Park Trees is considerable and may amount to as much as 70 per cent of the total timber volume assets of the county. Much of the timber is mature or semi-mature, and in the near future the standing volume is liable to be reduced as the older trees are felled. Whether the volume can be maintained or possibly increased thereafter depends on the better stems in the smaller girth classes being allowed to grow on and also, eventually, on the amount of planting, or tending of young stems, carried out.

REFERENCES

(1) *Forestry Commission Report on Census of Woodlands*, 1924. H.M.S.O., 1928. *Out of print.*

(2) *Forestry Commission Report on the Census of Woodlands, Woods of Five Acres and Over*, 1947-49. H.M.S.O., 1952. 12s. 6d.

(3) Ditto *English County Details*, 1947-49. H.M.S.O., 1953. 12s. 6d.

(4) Ditto. *Hedgerow and Park Timber and Woods under Five Acres.* H.M.S.O., 1953. 5s.

OBSERVATIONS ON KEITHIA THUJINA AND ON THE POSSIBILITY OF AVOIDING ATTACK BY GROWING THUJA IN ISOLATED NURSERIES

By T. R. PEACE,
Forest Pathologist

THE fungus *Keithia thujina*, which appears to be specific to the genus *Thuja*, has been known for quite a long time as a serious nursery disease of *Thuja plicata*. and other species of *Thuja* in Great Britain. Losses are often so high as to suggest that unless some remedy can be found, the growing of *Thuja* for afforestation may become uneconomic.

The fungus causes discoloration and withering of the foliage, and, in severe attacks, dieback of the shoots. It is capable of killing small plants and quite often does so, but is perhaps more serious because it often renders a high proportion of nursery plants unsuitable for field planting. Attack does not often develop on one-year-old seedlings, but can be very serious on two-year beds and on transplants of any age.

Very often quite badly infected plants will recover from the disease, especially if they can be lined out in good ground in the nursery; affected plants have less chance of survival in the forest, and only healthy or lightly attacked plants should ever be used for forest planting (Keatinge 1949). It occurs very commonly on plantation *Thuja*, but seldom develops to a damaging extent outside the nursery. Where it has done so, it has usually been in very sheltered and moist sites, and opening up the affected plantation by early brashing and removal of tall weed growth has resulted in the cessation of severe attack.

The fruit bodies of the fungus appear as small brown pinheads on the needles. Later they fall from the needles leaving small black cavities. The fungus has a very long active season, and, though no complete series of observations has been made, it has been recorded actively fruiting as early as the 11th April by the author, and as late as the 5th November by W. R. Day (unpublished note).

Another fungus, *Pestalozzia*, probably *P. funerea*, has been recorded causing very similar damage, by Laing (Laing 1929), and by the author on a number of occasions, but it is certainly far less common and far less important than *Keithia thujina*.

The fungus was first reported in the United States in 1913 (Durand 1913), but no doubt like many other American fungi it had escaped notice until then. Three years later it was reported doing considerable damage in Idaho (Weir 1916), but lack of later reports from America suggests that this was an exceptional development, and that generally it is not a damaging fungus, in what one presumes to be its native haunts.

In 1919 it was recorded in Ireland (Pethybridge 1919). Since then it has become fairly generally distributed in the British Isles, and has been reported from several other European countries, including Denmark, under its alternative name of *Didymascella thujina*, (Buchwald 1936), Belgium (Boudru 1945), and Switzerland (personal observation by the author in 1949).

Various suggestions have been made as to how it reached Europe from the United States. There is no evidence of nursery stock having been imported, but in a number of instances live North American conifers were brought to Europe, and this may have happened, without record, in the case of *Thuja*. Transmission on seed, as suggested by Pethybridge (Pethybridge 1919), or on infected debris mixed with seed, as suggested by Alcock (Alcock 1928), are both possibilities. It has been suggested that the disease could be controlled by copper sprays (Miles 1922, Alcock 1928), but these suggestions were not backed by experiment. Wide spacing in the nursery has also been suggested (Miles 1922, Evans 1950) with the idea of lessening the amount of spread from plant to plant. Another idea, several times put to the author verbally, is that of growing *Thuja* in mixture with other species, both in the seedbeds and in the transplant lines, to lessen the severity of attack. This is now the subject of experiment at Alice Holt, but no results are yet available.

Somewhat inconclusive spraying experiments were carried out in 1948 and 1949. Partial control was procured in one of the experimental nurseries in 1948 with a proprietary lime sulphur spray, but this result was somewhat negatived by the failure of the same substance that year, and in 1949, in other nurseries. The long season of fungal activity is probably one of the main reasons underlying the difficulty of control by spraying.

It had been noted in several places that infection was particularly bad in nurseries which had a *Thuja* hedge, and this suggested that most of the infection on newly raised plants came from near at hand. On a number of occasions nurseries had been found which were free of the disease, and it seemed possible that these were nurseries which the fungus had not yet reached. They were probably nurseries to which *Thuja* had been taken only in the form of seed, and which were well isolated from existing plantations or individual trees of *Thuja*.

An outstanding example of this freedom was Tulliallan nursery just north of the Firth of Forth, which was still *Keithia*-free after many years of raising *Thuja*, but into which the genus had only entered as seed.

In view of the obvious difficulty of elaborating a satisfactory spraying programme and, assuming this could be done, the cost of spraying throughout the season, it was decided to concentrate on experiments designed to test the possibility of raising *Keithia*-free *Thuja* in isolated nurseries. As far as the Forestry Commission is concerned, this would be a perfectly feasible solution. The numbers of *Thuja* raised are small compared to the nursery area, so that there would be no difficulty in concentrating the raising of *Thuja* in a few selected isolated nurseries, or even if need be, starting special nurseries for that purpose. It must be admitted that this solution is not so much use to a private estate or commercial nurserymen, who may be unable to find a sufficiently isolated site, or who, for labour or other reasons, may wish to continue raising *Thuja* in an infected nursery. The possibility exists of leaving the nursery free from *Thuja* for a period of years in the hope of the fungus dying out, and then starting again from seed; but no information is available on how long it would have to be left, and of course this practice would be of no value if there were established *Thuja* anywhere near.

The work in isolated nurseries was started in 1948. In that year *Thuja* was sown in four nurseries, which satisfied two requirements (*a*) that *Thuja* had not been grown in them previously, and (*b*) that no *Thuja* were growing in the vicinity of the nursery. No distance was defined for (*b*), nor was any accurate survey made to discover the nearest *Thuja*. It was considered of more value in the first instance to accept what the average forester would select as an isolated nursery.

During the first two years half the seed sown was treated with a fungicidal seed dressing, with the idea of testing the possibility of the disease being seed borne. But this treatment was abandoned before any of the nurseries concerned had become infected. A summary of the results to date is given in Table 53.

PERIOD OF FREEDOM FROM KEITHIA OF ISOLATED NURSERIES

Table 53

Nursery	Years free before infection	Years free where still uninfected
Montreathmont	3	—
Mabie	3	—
Devilla	—	7
Kerry	5 (but infection accidental)	—
Littleburn	3	—
Newcastleton	4	—
Strathlachlan	—	5
Kinver	—	4*
Pitfichie	—	4
Ampthill	—	3*
Culmhead	0 (infected first year)	—

Note: *Not yet examined in 1954.

Some notes on the individual nurseries are given below.

Montreathmont. *Keithia* was definitely recorded on the plants in 1951, but there is a suspicion that it may have been present in 1950, since a few browned needles without fruit bodies on them were noted. No *Thuja*, infected or otherwise, could be found within a mile radius of the nursery, so that either spores of the fungus travelled further or else they were carried in on plants of another species or on tools or clothing.

Mabie. Here again the fungus was definitely recorded in 1951, but may have been present in 1950. Quite heavily infected *Thuja* were found in the grounds of Mabie House about 0.6 miles away from the nursery. It can, therefore, be concluded that this distance is insufficient to prevent infection, at any rate where, as in this case, the intervening ground was largely open fields.

Devilla. This nursery has the longest record of freedom of any of those in the experiment. It is a good nursery silviculturally for *Thuja*, and high quality plants have been raised throughout the experiment.

Kerry. This nursery is at a high elevation in Wales, and was in fact far too exposed for *Thuja*. For this reason no further sowings were made after 1948, but as a matter of interest the original plants were retained in the nursery. In 1953 infected plants were brought in by mistake from another nursery, and, although the test plants were not yet infected, the experiment was abandoned.

Littleburn. The start of the experiment here was delayed by the failure of the 1950 sowing. Since then high quality disease-free plants have been raised each year, until 1954 when infection appeared. The source of infection has not been traced.

Newcastleton. After 1951 this nursery was abandoned and the plants were moved to a vacant plot of ground in the immediate vicinity. For this reason no further sowings were made. Heavy infection appeared in 1954 from a source not yet traced.

Strathlachlan. This nursery was given up almost as soon as the experiment started. The *Thuja* plants, however, which have grown very slowly, owing to the exposed situation and browsing by deer, have been retained.

Kinver. This nursery is not far from Birmingham, and illustrates the possibility of getting a suitable nursery for *Thuja* raising in a less remote district. High quality disease-free plants have been raised consistently since the first sowing in 1950.

Pitfichie. This nursery is in a small clearing in the middle of a large block of pole-stage conifers, mainly spruce and pine. After the failure of the 1950 crop no further difficulties have been experienced.

Ampthill. All the nurseries considered above were selected because *Thuja* had not previously been grown in them. Ampthill, on the other hand, was selected because all the *Thuja* in the nursery were found to be *Keithia*-free. So far, apart from one seed failure, high quality disease-free plants have been raised.

Culmhead. This nursery, like Ampthill, was selected because the *Thuja* already in it were free of *Keithia*. Unfortunately, no survey was made round the nursery before its selection. In 1951, while the experimental sowing was still too young to become infected, *Keithia* was found on transplants. The most probable source was some heavily infected ornamental *Thuja* in a garden only 0.3 miles from the nursery, and with only a narrow belt of trees in between.

It will be noted that, of the six nurseries which have so far become infected, two were quite near infected *Thuja* trees and one was accidentally contaminated. In the case of Montreathmont the infection remains unexplained. No information is yet available on the sources of infection at Newcastleton and Littleburn.

It must be admitted that these results are rather disappointing. While it would appear to be possible to raise *Thuja* free from *Keithia* for a period in any new isolated nursery, one cannot, apparently, expect this immùnity necessarily to last very long. Nevertheless this method does offer, for the moment, the best chance of raising healthy *Thuja*, and the whole idea cannot be condemned until investigation has been carried out to ascertain the cause of the failure in the two nurseries, which became infected in 1954. The experiment will, of course, be continued in those nurseries still unaffected.

REFERENCES

ALCOCK, N. L. (1928) "Keithia thujina, a disease of nursery seedlings of Thuja plicata." *Scot. For. Jour.*, xlii, 2, pp. 77-9.

BOUDRU, M. (1945) "La rouille des aiguilles du Thuya geant (*Thuja plicata* Don)". *Bull. Soc. For. Belg.*, lii, pp. 69-75.

BUCHWALD, N. F. (1936) "En ny svampesygdom i Danmark. Didymascella thujina paa Thuja plicata." *Dansk Skogforen. Tidsskr.*, pp. 51-59.

DURAND, E. J. (1913) "Keithia thujina." *Mycologia*, v, l, pp. 6-11.

EVANS, J. D. D. (1950) "Red Cedar and European larch in mixture." *Quart. Jour. For.*, xliv, 3, pp. 137-42.

KEATINGE, G. (1948) "Keithia thujina." *Quart. Jour. For.*, xlii, 4, pp. 199-200.

LAING, E. V. (1929) "Notes from the Forestry Department, Aberdeen University." *Scot. For. Jour.*, xliii, i, pp. 48-52.

MILES, A. C. (1922) "Keithia on Thuja plicata." *Gard. Chron.*, lxxii, p. 353.

PETHYBRIDGE, G. H. (1919) "A destructive disease of seedling trees of Thuja gigantea." *Quart. Jour. For.*, xiii, pp. 93-7.

WEIR, J. R. (1916) "Keithia thujina, the cause of a serious disease of Western Red Cedar." *Phytopath.*, vi, 4, pp. 360-3.

EXPERIMENTS WITH CHEMICAL REPELLENTS FOR PROTECTING TREES AGAINST RABBITS

By G. D. HOLMES,
Assistant Silviculturist

THERE are very few areas in Britain where rabbits do not exist, and at the present time they are undoubtedly the most destructive forest pests in the country. Rabbits can cause catastrophic damage to newly planted trees and young established plantations, and as a result it is almost universal practice to protect new plantations with wire netting. Netting is expensive, and does not provide infallible protection, whether used as a complete fence around a planted area.

or as netting "sleeves" around individual trees. Consequently, even in fenced areas constant vigilance is necessary as only a few rabbits finding their way into a new plantation may result in the death of a large proportion of trees. Examples of damaged and undamaged trees are shown in Photos 12 and 13.

The only fully satisfactory method of preventing losses due to this pest would be the elimination of the rabbit populations through extermination campaigns. Some efforts have been made in this direction and serve to illustrate what can be achieved by such methods. Some such reductions in the rabbit populations were made during the 1939-45 war as a result of efforts by the War Agricultural Executive Committees. More recently concerted action by the Forestry Commission, and owners and tenants of properties adjacent to its forests has resulted in a virtual extermination of the rabbit population over an area of about 25,000 acres in the Fochabers district of Morayshire. As a result, new plantations in that area may now be planted without enclosure by rabbit proof netting.

Myxomatosis, which appeared in England in 1953, may go a long way towards effecting a useful reduction of the population of rabbits. But it is still too early to forecast what its effects may be, and hence it would be unwise to neglect other methods of control or the avoidance of damage.

The severity of rabbit damage and the high cost of fencing has stimulated interest in alternative methods for protecting young plantations, including the use of chemical repellent materials applied on or around the trees. The idea of utilising repellent chemicals for protecting growing plants against damage by animals is not new. During the last twenty years a very wide variety of materials thought to have repellent properties have been tested for horticultural and forest crops in various parts of the world, notably in the United States and Germany. Much of this work has been summarised in a comprehensive review by Thompson (7) in 1953.

Most of the materials so far tested rely on obnoxious colour, touch, taste or odour for their repellent properties, although some are reported to provide mechanical protection by drying after application, to form a hard coat on the plant. Materials of the latter type are normally unsuitable for application to young trees but have shown some success when applied as bark applications to larger trees. A good repellent should be cheap, easy to apply, and remain effective at least through the season of application, and preferably for a longer period. It should not injure the tree to which it is applied, and it should be relatively non-volatile and insoluble in water.

Some materials have been in use for many years. In Germany for example acid-free coal or wood tar has been used for over a century as a repellent for protecting the stem and bark of trees. Preparations of this type, including coal tar, wood tar, creosote and bituminous material, are among the most commonly recommended repellents. In general they have given quite good results providing care is taken in selection of the materials. Tars of excessive acidity or alkalinity can be injurious to the tree, similarly tar which needs to be warmed for application may be dangerous. Recent experiments by Fourage and Detroux (4) tested a variety of such materials for the protection of newly planted trees of seventeen hardwood species. Coal tar was found to give effective and durable protection for ash and *Robinia*, while creosote was found promising for beech, American oak and sallow. Vegetable tar was found to be effective only during the year of treatment, but it was also the least injurious to the trees. The conclusion seems to be that tar preparations can be most effective, but can cause direct injury to the trees and should be used with caution.

In 1941, Cardinell, Toenjes and Hayne (2) tested over 200 materials for protection of fruit trees and found the only safe and effective repellent was a mixture of resin and alcohol applied to stems at 7 lb. resin per gallon of alcohol. Baumgartner and Powell (1) in 1949, obtained most promising results with a repellent, zinc dimethyldithiocarbamate-cyclohexylamine complex (Z.d.c.) which is marketed in the United States as a deer repellent. Applied to stems together with an adhesive compound polyethylene polysulphide, the material provided almost complete protection against deer. It is also claimed that the chemical is an effective rabbit repellent. This was confirmed in 1951 by Welch, Graham and others (9), who tried a number of repellents for protection of apple shoots against rabbits. Z.d.c., tetramethyl thiuram disulphide, and actidione all gave a high degree of protection. Actidione is described by Welch (10) 1954, as possessing about twenty times the repellent activity on a weight basis, shown by other promising compounds. This material, which in this paper will be referred to by the chemical name "cycloheximide", is an antibiotic produced by certain strains of *Streptomyces griseus*. Its repellent properties were first noted by Traub, DeWitt, Welch and Newman (8) 1950, who noted that it was highly repellent to mice and rats even at extreme dilutions in water.

Another promising material is compound 96A, formulated by the U.S. Fish and Wildlife Service as a rabbit repellent. The compound is a mixture of resin, asphalt emulsion, copper carbonate, and lime sulphur, with ethylene dichloride as a solvent. Garlough, Welch and Spencer (5) 1942, found the material promising, but Welch and Graham (9) 1951 found it did not compare favourably with Z.d.c., tetramethyl thiuram disulphide, and actidione. Welch (10) 1954, in a review of chemical repellents for rodents reports that recent studies have demonstrated the value of Z.d.c., tetramethylthiuram monosulphide, tetramethylthiuram disulphide and trinitrobenzene complexes. Trial applications using these compounds with suitable adhesives effectively protected elm and apple trees against rabbits throughout the dormant season. Repellent 96A and resin-alcohol were less effective. This work also demonstrated the importance of using proper adhesives to secure maximum duration of the effectiveness of the repellents. In England a trial of 96A and Z.d.c. for protecting apple shoots at East Malling by Coker (3) 1950, showed that 96A gave better results than Z.d.c. A later experiment by Thompson and Armour (6), 1952, using apple rootstocks, showed that resin-alcohol, bone oil, and 96A gave considerable protection against rabbits. Z.d.c. on the other hand gave no protection at all, and is reported to have been washed off the plants by rain. It seems that the inconsistency between the results of several workers with Z.d.c. may be due to variation in the efficiency of the adhesives used with the repellent. Recent work (unpublished) by Revertex, Ltd. in England indicates that natural and synthetic rubber latex may be useful as adhesives and carriers for repellent compounds, and in addition may provide a high degree of protection in themselves.

Numerous enquiries have been received by the Forestry Commission from private woodland owners and others, regarding the practical value of rabbit repellents, and there is clearly considerable interest in the possibilities with such methods. At the end of 1952 it was decided trials should be made to evaluate experimentally the usefulness of the more promising repellent materials for application under forest conditions. Accordingly, a series of trials were laid down in 1953 and 1954 at Didlington, Thetford Chase Forest, East Anglia, on a selected area exposed to very heavy rabbit grazing. These first experiments have been restricted to newly planted trees, and so far no attempt has been made to test repellents for protection of the bark and stems of larger established trees. In most cases the repellents under trial have been applied to the whole aerial part of the plants by painting the compounds on to the trees shortly after planting. No costing of the various treatments was done at this stage, as it was first necessary to find some effective material, before the economics of its use could be considered.

1953 Trials of Newly Planted Beech

The first experiments were carried out on two-year-old transplants of beech, planted and treated in the winter of 1952. Planting was done in unit plots of sixteen plants per treatment arranged in a replicated randomised block design. There was some variation in the natural vegetation on the ground at the time of planting. It was thought that the type of ground cover might influence the incidence of rabbit attack on planted trees, so the experimental area was divided into three broad types according to vegetation, and the experiment was laid out in discrete blocks on each type. The three types of ground cover distinguished were 1, bracken cut some weeks before planting; 2, uncut bracken; and 3, grasses, moss and scattered clumps of gorse, all closely grazed by rabbits.

The treatments tested in 1953 were as follows:

1—Plots netted with $1\frac{1}{4}$ inch mesh netting buried at the foot to exclude rabbits.

2—Commercial resin, applied in solution at 8 lb. per gallon of industrial methylated spirit.

3—Resin as in 3, applied at 3 lb. per gallon of spirit.

4—"Revertex", natural rubber latex as 75 per cent emulsion in water.

5—Zinc dimethyldithiocarbamate-cyclohexylamine complex (Z.d.c.) at 10 per cent in natural rubber latex.

6—Z.d.c. at 10 per cent in starch paste.

7—Cycloheximide at 4 per cent in natural rubber latex.

8—Cycloheximide at 4 per cent in starch paste.

A treatment involving a volatile offensive smelling compound was applied in a separate trial with widely spaced plots. This was done to avoid the possibility that the proximity of such a material might affect the incidence of attack on treatments in adjoining plots. The aromatic material tested was bone oil, an offensive smelling oil obtained by distillation of bones. All repellent treatments were applied with a brush immediately after planting on 9-10th December, 1952. An exception was cycloheximide which was not available in December and was applied to newly planted trees one month later, in mid-January, 1953. Following treatment all plants were examined at monthly intervals and assessed for the nature and extent of injuries caused by rabbits.

In nearly all cases injuries were a result of biting and removal of shoots, and tabulation of the type of injuries into gnawing, bark stripping, etc., reveals little of interest. Examination of plants from December 1952, until November 1953, showed that only netting wholly prevented damage by rabbits, though most of the repellent treatments gave some degree of protection for several months after application (vide Fig. 15).

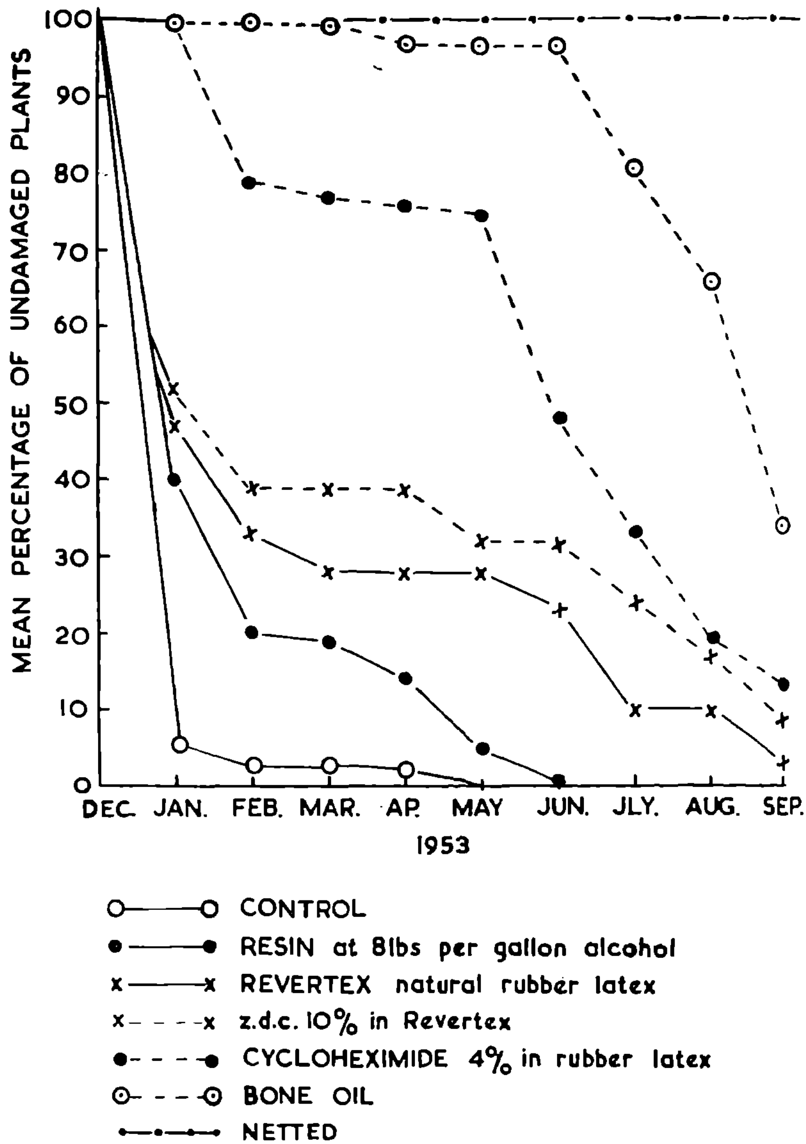


Fig. 15. Incidence of Rabbit Damage to Two-year-old Beech Plants during Nine Months after Planting (1953 Trial).

Untreated control trees were extensively damaged within one week of planting, and by mid-January, four weeks after planting, 90 per cent of plants were dead or severely injured. Trees in plots fenced with $\frac{3}{8}$th inch or $1\frac{1}{4}$ inch mesh netting remained undamaged throughout the period of the experiment. The most successful repellent compounds were bone oil and cycloheximide. Bone oil gave almost complete protection for six months, after which its effectiveness declined rapidly until by September over 60 per cent of trees had been attacked. Cycloheximide is not strictly comparable with other treatments as it was applied one month later than other compounds, thereby escaping exposure to the severe rabbit attack occurring on many plots during December 1952. The results with this compound were promising during the first four months after treatment, and application in rubber latex or starch paste as adhesives gave equal results. Z.d.c. applied in starch paste was completely ineffective, and application in rubber latex gave no added protection to that attributable to rubber latex applied alone. Resin-alcohol at both 3 lb. and 8 lb. per gallon gave disappointing results. The preparation failed to adhere to the smooth bark of the beech plants and was almost completely weathered off within six weeks of application. Assessments in November, eleven months after planting, showed that there were large numbers of damaged plants in all repellent treatments, but also there were considerable differences between treatments in the severity of the damage. (vide Table 54.)

MEAN PERCENTAGES OF DAMAGED AND UNDAMAGED PLANTS RECEIVING VARIOUS PROTECTIVE TREATMENTS ELEVEN MONTHS AFTER PLANTING

Table 54

Treatment (applied Dec. 1952)	Assessment November 1953		
	Percentage of Undamaged Plants	Percentage of Slightly Damaged Plants	Percentage of Dead, and Severely Damaged Plants
Control	0	0	100
Netting	100	0	0
Bone oil	30	47	23
Cycloheximide (4%)	12	60	28
Z.d.c. (10% in "Revertex")....	9	26	65
"Revertex" (75%)	4	31	65
Resin	0	15	85

Inspection of the above table will show that for plots treated with Z.d.c., "Revertex", and resin, the proportion of damaged plants which were dead or severely damaged was considerably greater than for plots treated with bone oil or cycloheximide. This point was shown up again when the heights of surviving plants were measured at the end of 1953 (see Table 55).

MEAN PERCENTAGES OF LIVING BEECH PLANTS, AND HEIGHTS ELEVEN MONTHS AFTER PLANTING, UNDER DIFFERENT PROTECTIVE TREATMENTS

Table 55 Original height when planted: 6 inches

Treatment (Applied December, 1952)	Assessment November, 1953	
	Percentage of Living Plants	Mean Height of Living Plants (inches)
Control	34	1.65
Netting	98	10.13
Bone oil	78	7.85
Cycloheximide (4%)	81	7.10
Z.d.c. (10% in "Revertex")	60	4.50
"Revertex" (75%)	52	4.90
Resin	50	2.90

All treatments show greatly reduced height growth as compared with fenced plots, and in some cases the plants were smaller at the end of the year than at the beginning. Unfortunately these figures are not simply a reflection of the amount of rabbit damage, as some chemicals were injurious and affected tree growth.

Both bone oil and cycloheximide caused a retardation of bud development in the spring, and even though these treatments prevented serious rabbit damage, shoot development was abnormal and slow in comparison with netted trees.

Differences in the incidence and severity of rabbit damage were observed between plots of similar treatments on the three vegetation types mentioned earlier. Damage was relatively less severe on trees planted in uncut bracken than on those planted in cut bracken or close cropped grass and gorse. Some treatments, notably "Revertex" and Z.d.c. in "Revertex" which gave poor protection to trees on cut bracken and cropped grass, gave a high degree of protection until June 1953 on uncut bracken.

From a practical standpoint the results of this trial were not encouraging as no repellent preparation gave complete protection for longer than three months after planting, and the most promising compounds appeared directly injurious to the trees. However, interesting pointers on the relative effectiveness of the materials under test were obtained, and the work was extended on the same site in the winter of 1953 to include tests on three hardwood species.

1954 Trials with Beech, Oak and Ash Transplants

The investigation was conducted on similar lines to the 1953 trials, treatments being applied to the trees by means of a brush immediately after planting in November, 1953. The repellents tested including resin-alcohol, cycloheximide and bone oil and three proprietary repellent preparations. The proprietary compounds were 1, "Sinoxyd-F", a quick-drying bituminous emulsion marketed in Germany as a deer repellent; 2, "Herbasan", a material of unspecified composition also produced in Germany as a deer repellent; and 3, "C.G.A. Tree Bark Protector", a compound containing animal oils marketed in Britain as a rabbit repellent.

Two-year-old transplants of beech and oak, averaging 16 inches and 13 inches in height respectively, were used in the experiment. The ash were planted as four-year transplants averaging 45 inches in height. Repellent treatments were applied immediately after planting for all species. The whole aerial shoot of the beech and oak plants were treated, but in the case of ash the repellents were applied only to the basal 18 inches of stem of each plant. Untreated trees of all species were attacked by rabbits immediately after planting, and damage was severe within four weeks. Both beech and oak showed extensive injury through biting and removal of shoots, and untreated ash plants exhibited extensive bark stripping over the lower 12 inches of stem.

The degree of protection afforded to beech and oak in the several treatments is summarised in Fig. 16, which gives graphical representations of the percentages of undamaged plants at monthly intervals after planting and treatment.

Netting gave complete protection to both species throughout the period. At the time of writing, information is available only to June 1954, i.e. for seven months after planting. Cycloheximide was rather more successful than in 1953 and gave almost complete protection during the first six months of the 1954 trial. "Herbasan" has also given good results. Resin-alcohol was less successful, providing almost full protection for up to three months in the case of beech, after which time increasing injury had occurred. Bone oil gave most disappointing results in view of its relative efficiency in the first months of the 1953 trial.

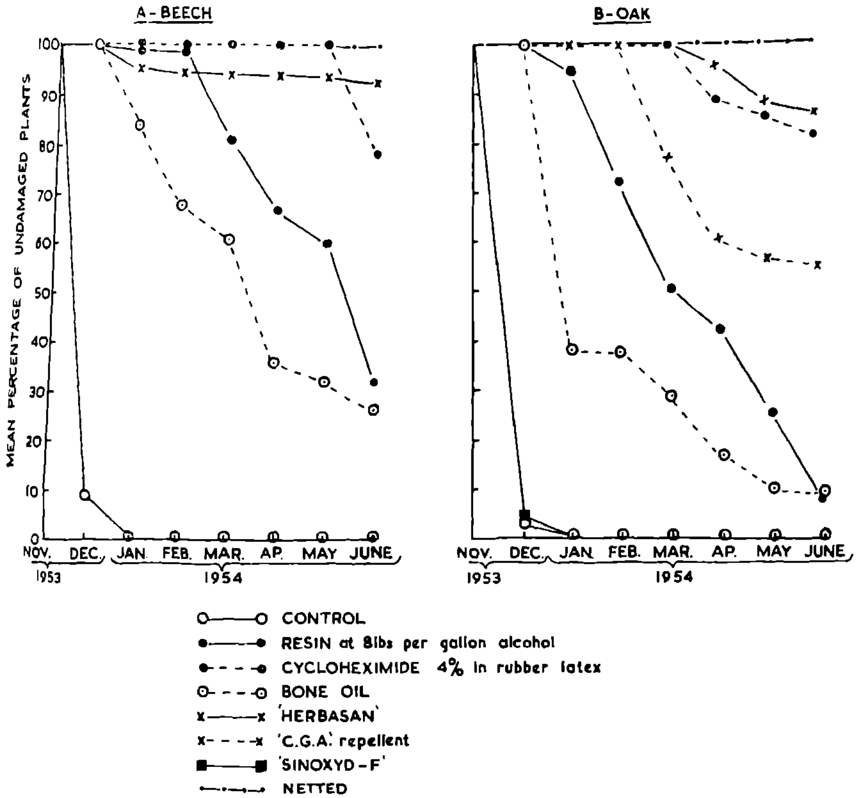


Fig. 16. Incidence of Rabbit damage to Two-year-old Beech and Oak Plants during Seven Months after Planting (1954 Trial).

"Sinoxyd-F" and "C.G.A." repellents were not tested on beech, but results on oak (Fig. 16, B), and ash (Table 56), indicate that Sinoxyd-F was almost completely ineffective, but "C.G.A." repellent gave temporary protection for both species. The results of basal treatment of the large ash plants appeared good, as with the exception of Sinoxyd-F all treatments gave protection for six months.

But many of the treatments checked tree growth, and in some cases, notably cycloheximide, "Herbasan" and "C.G.A." repellents, prevented a large proportion of trees coming into normal leaf in the spring. Table 56 shows the position in June 1954, seven months after planting and treatment. Columns 3, 5 and 7 of this table show the percentages of plants in leaf among the plants undamaged by rabbits, and provide a measure of the injurious effects of the treatments on the plants. Oak was most sensitive, being killed outright on cycloheximide plots, and showing very poor development after treatment with Herbasan and C.G.A. repellent. Beech was less sensitive, but here also there was a pronounced check of bud development from Herbasan and cycloheximide. Ash, being large plants, were treated only at the base, and generally showed less treatment damage than oak and beech which were treated overall. The exception to this was cycloheximide, which as for oak, was completely fatal to the trees.

Resin was the only compound almost completely innocuous to trees and this was effective as a repellent only in the case of ash. The resin mixture failed to adhere to oak and beech, and the rate at which it was weathered off seems largely responsible for the poor protection in these cases. No similar explanation can be offered for the relative failure of bone oil for protection of oak and beech, and the difference in its effectiveness between 1953 and 1954 trials is most puzzling.

MEAN PERCENTAGE OF PLANTS SHOWING NO RABBIT DAMAGE AND THE PERCENTAGE OF THESE PLANTS IN LEAF—SEVEN MONTHS AFTER PLANTING, UNDER VARIOUS PROTECTIVE TREATMENTS

Table 56 Assessment—June 1954

Treatment	Beech		Oak		Ash	
	Percentage of plants undamaged by rabbits	Percentage of Un-damaged plants in leaf	Percentage of plants undamaged by rabbits	Percentage of Un-damaged plants in leaf	Percentage of plants undamaged by rabbits	Percentage of Un-damaged plants in leaf
Control	0	—	0	—	0	—
Netting	100	100	100	100	100	100
Resin (8lb. per gallon alcohol)	32	100	8	72	99	96
Cycloheximide .... (4% in latex)	78	60	81	0	100	0
Bone oil	27	75	11	50	86	70
"Herbasan"	97	40	88	30	100	60
"C.G.A." repellent	Not tested		56	16	100	70
"Sinoxyd-F"	,,	,,	0	—	0	—

Cycloheximide and "Herbasan" were the most effective repellents but both were injurious to the trees.

An additional experiment was planted in November 1953 to determine the minimum effective repellent concentration of cycloheximide when applied in rubber latex or starch paste adhesives to young beech plants. Assessment up to seven months after treatment showed little difference between the two. All concentrations tested, which ranged from 0.5 per cent to 4.0 per cent cycloheximide in solution, gave a high degree of protection throughout the first five months of the trial. At seven months after planting many trees had been attacked and only the 4.0 per cent solution in latex provided a high degree of protection (vide Table 57).

MEAN PERCENTAGES OF UNDAMAGED BEECH PLANTS AND THE PERCENTAGE OF THESE PLANTS IN LEAF SEVEN MONTHS AFTER TREATMENT WITH A RANGE OF CONCENTRATIONS OF CYCLOHEXIMIDE

Table 57

Treatment	Percentage of Plants undamaged by rabbits	Percentage of undamaged plants in leaf
Control-unprotected	0	—
0.5% solution cycloheximide in rubber latex emulsion	25	100
1.0% ,, ,, ,,	33	90
2.0% ,, ,, ,,	46	90
4.0% ,, ,, ,,	75	61
0.5% ,, in starch paste	20	83
1.0% ,, ,, ,,	25	56
2.0% ,, ,, ,,	58	28
4.0% ,, ,, ,,	36	34

The figures in column 3 indicate that the injurious effects of cycloheximide on the plants increase with concentration and appear negligible at the lower rates in latex adhesive. Application in starch appears to have caused greater injury to the plants than application in latex.

Summary and Conclusions

The repellent compounds examined during 1953 and 1954 were applied only to newly planted deciduous hardwood species in the winter. Some of the compounds tested caused serious injury to the trees particularly where repellents were applied over all aerial shoots of the plants as in the case of oak and beech. Basal treatment of large plants was generally less injurious and indicates that any practical use of these preparations is likely to be with this method of treatment. Applications to evergreen conifers have not been critically tested, but small trials on Scots pine transplants indicate that some compounds, notably bone oil, are injurious, while resin, rubber emulsion and starch paste appear harmless. The results of 1953-54 trials on hardwoods under forest conditions show a number of inconsistencies in the results obtained with several compounds. However, the main conclusions from these preliminary investigations may be summarised as follows.

1. No chemical repellent remained effective in protecting young plants against damage by rabbits for longer than six months after application. The most recent trials show promising results with cycloheximide and "Herbasan" for six months after treatment. Both these compounds however were directly injurious to young trees, causing many deaths, and further work is required to examine alternative methods of application.

2. Bone oil, and resin-alcohol, have given inconsistent and disappointing results. The resin mixture was repellent for a time but was weathered off the plants very rapidly and warrants further trials with an efficient adhesive.

3. Z.d.c. was almost completely ineffective as a repellent applied in starch paste or rubber latex emulsion and should be tried with other adhesives. Rubber latex emulsion ("Revertex") which was used as an adhesive was shown to be harmless to the trees and to have some repellent properties when applied alone.

4. The proprietary repellents, "Herbasan", and "C.G.A. Tree Bark Protector" gave protection for six months in 1954, but both were injurious to trees, except when applied only as basal treatments to larger trees. "Sinoxyd-F" was almost completely ineffective for protection of young oak and ash plants.

5. The area selected for these experiments supports an exceptionally high rabbit population and provided a most rigorous test of all compounds. The incidence and severity of rabbit damage to planted trees was found to vary considerably according to the type of ground vegetation into which the trees were planted. The least injury occurred to trees planted in uncut bracken, and under these conditions quite a high degree of protection was given even by the less generally effective treatments such as resin and "Revertex". This point is of some importance as it does indicate that failure of a compound on exposure to the extremely heavy rabbit grazing occurring over most of the experiment, does not necessarily mean that the compound will fail under other conditions. In areas less exposed to grazing, or in localities with a lower rabbit population it is possible that the compound may provide protection for a time.

An efficient repellent would undoubtedly be a most valuable aid to the forester, but it must be harmless to the trees and provide lasting protection without requiring repeated application at frequent intervals. The immediate aim of these investigations was provision of a compound and technique which would give complete protection to treated trees for one full season without re-application. This object has not been achieved, but it is proposed to continue and extend the present tests to include alternative methods of application and other promising repellents and adhesive materials.

REFERENCES

1. Baumgartner, L. L., and Powell, S. E. (1949). *Coutr. Boyce Thompson Inst.*, 15 (411-20). *For. Abs.*, 11, No. 1474.
2. Cardinell, H. A., Toenjes, W., & Hayne, D. W. (1941). *Mich. Agric. Exp. Sta. Quart. Bull.*, 24 (65-8).
3. Coker, E. G. (1950). *Rep. E. Malling Res. Sta.* (87-9).
4. Fourage J., and Detroux, L. (1953). *Bull. Soc. Roy. For. de Belge*, 60 (377-85).
5. Garlough, F. E., Welch, J. F., and Spencer. H. J. (1942). *Conserv. Bull. U.S. Fish and Wildlife Serv.* No. 36.
6. Thompson, H. V., and Armour, C. J. (1952). *Plant Path,*. 1 (18-22).
7. Thompson, H. V. (1953). Commonwealth Agric. *Bur. For. Abs.*, 14, No. 2 (129).
8. Traub, R., DeWitt, J. B., Welch, J. F., and Newman. D. (1950). *J. Amer. Pharm. Assoc.* (Scient. Edn.), 39 (552).
9. Welch, J. F., Graham (1951, Wildlife Res. Lab. *Denver, Col., Quart. Rep.* (April-June).
10. Welch, J. F. (1954). *J. Agric. Food Chem.*, 2 (142-9).

THE STATUS OF THE PINE LOOPER MOTH (BUPALUS PINIARIUS L.) IN BRITAIN IN 1953

By D. BEVAN,
Assistant Entomologist

SEVERAL *Lepidoptera* known to be serious pests of pine on the continent of Europe are indigenous to the British Isles, and have been noticed in fairly large numbers from time to time. No serious attempt, however, had been made to find out their status and potential value as pests in this country until, in 1952, investigations were started by the entomology section of the Research Branch. The preliminary reconnaissance and check on life cycles was carried out at Thetford Chase Forest in East Anglia, and it was soon established that, of the pest species present, the Pine Looper Moth, *Bupalus piniarius*, was the most numerous; the Pine Beauty, *Panolis flammea* Hueb., was found to be common also, whilst the Nun Moth *Lymantria monacha* L. appeared to be a rarity. Attention soon became drawn to the development of an accurate method of Pine Looper Moth population assessment as a prime requirement for further investigation into the epidemiology of this insect.

In the summer of 1953, the Pine Looper Moth came into prominence through the defoliation of over 100 acres of pinewoods, aged around thirty years, at Cannock Chase Forest in Staffordshire. To spread information about it, so that any further outbreaks might be promptly reported, a leaflet entitled *Pine Looper Moth* was published in 1954 (Forestry Commission Leaflet 32, H.M.S.O., 9d.); this gives an illustrated account of the insect itself, its life history, and the nature of the damage done to pines.

Population Assessment Method

The method which has proved most successful on the continent is the counting of pupae in the soil and humus of sample plots of known size, and this method was therefore applied.

After some preliminary trials into the number and distribution of samples required for accuracy, statistical analysis showed that an extremely low rate of sampling gives satisfactory results. The method in general use now, therefore, is the counting of pupae in plots, each one yard square, laid down at the rate of five per forest compartment (say one per five acres), and placed in such a way as to straddle the compartment. Where a complete knowledge of the population variation is required, then every compartment of an age likely to be involved is covered; this, for instance, may be necessary for the demarcation of areas to be treated during infestations. If it is merely required to establish whether or not there is anywhere present a potentially dangerous population, it is sufficient to sample in representative compartments through the area. *Bupalus piniarius* is a pest of pine, at the pole stage or older, and such crops are therefore selected as those most likely to hold high numbers. At the same time an effective distribution of the samples is an essential. The proportion of compartments which should be sampled will depend very much on the variation in site and crop. Where the forest is fairly homogeneous it may be sufficient to sample in only 10 or 15 per cent of them, but in hilly country, or where the forest is split into small blocks, or where there is a great mixture and variety of age classes, it may be necessary to sample practically every compartment. The intensity of sampling must also be to a certain degree adjusted to the populations encountered. If high populations are revealed by the initial counts, more information will probably be required as to the extent of the area so affected, and further supplementary samples must therefore be taken.

Significance of the Data from Pupal Counts

Interpretation of these data has to be made with some caution. We have little experience of this insect in Britain, and we therefore must be guided by, although we need not accept, information from continental sources. In Germany, in 1930, the practice was to take six pupae per sq. metre (approximately equal to a square yard), as a pupal count which indicates a population so dense that it may, in the following summer, cause a loss of half the foliage to the pines amidst which it is found. We have some reason to believe that a higher count would be necessary to produce a similar degree of damage in Britain. In fact, we have found such populations where no resulting defoliation took place. However, we can say that counts between 0.1 and 1 per square yard represent an endemic population, and six must be taken as well above normal. Where a population of six pupae per square yard is found there will certainly be some signs of feeding on the needles, but not necessarily will there be browning of the foliage as a whole.

Results of Survey

Population assessments during the winter of 1952/53 were carried out at Culbin Forest, Morayshire, as well as at Thetford Chase, as a great number of adults had been seen flying there during the summer. The overall pupal density at Thetford was about 0.1 per square yard, a quite definitely measurable quantity of the endemic order. At Culbin, however, compartments with pupal counts of up to 6.9 per square yard were discovered.

As a consequence of the complete defoliation of about 100 acres of Scots pine at Cannock Chase during the summer and autumn of 1953, and of a considerable increase in population at Culbin, it was then decided to undertake as complete a survey as possible in the main pine areas throughout Britain. The following is a summary of the results of this survey, which was carried out in the winter of 1953/54.

Scotland, North Conservancy

Black Isle Region of Ross-shire. Pupal counts at Millbuie and Findon Forests were of the order of 1 to 2 per square yard. Kessock Forest had similar numbers with the exception of the older Scots pine in Compartments 15 and 16, where up to 6.4 pupae were found per square yard. Kilcoy Forest had generally rather higher counts particularly in Compartments 19, 15/16 and 17, carrying Scots pine about 80 years old, which had 17.2, 26.4 and 19.2 pupae per square yard respectively. These last three compartments were considered liable to some defoliation in 1954.

Scotland, East Conservancy

Culbin Forest, Moray. Sampling was carried out in all compartments of a suitable age. Pupal counts ran up to 40 per square yard. Just under half of the established forest area showed a pupal density of at least 15 per square yard, and about a quarter of it a density of between 6 and 15 per square yard; the remainder having less than 6. Lower counts were found to the west in the older woodland area where damper soil conditions exist, and also to the east in the old rather open mature Scots pine round Binsness. It was also noticed that high counts were usually obtained in plots which were placed on dunes as compared with those on shingle beds. No defoliation or browning of the foliage was noticed in the autumn of 1953, though the general thinness of the crowns and frequent needle discoloration at Culbin rather confuses the issue. The highest pupal counts recorded were: for Scots pine, Compartment 6, thirty years old, 40.4 per square yard; for Corsican pine, Compartment 27, thirty years old, 22.5 per square yard; and for *Pinus contorta*, Compartment 43, twenty-four years old, 13.5 per square yard.

Roseisle Forest, Moray. This forest is growing on a sand dune area, under rather similar conditions to Culbin, but is younger. There were surprisingly high counts on the dunes in Scots and Corsican pines when account is taken of the age of the crop, e.g. Compartment 73, Corsican pine, twenty years old with a pupal count of 10.6. The highest count was in Compartment 30, Scots pine, twenty-one years old with 14.4.

Durris Forest, Kincardine. The pupal count was generally low and less than 1 per square yard, the highest count of 1.8 being in Compartment 66, Scots pine, 34 years old.

Altcailleach Forest, Aberdeen. There are few middle-aged crops, most of the blocks being rather open 70-90-year-old Scots pine, or young pole plantations. The pupal count ranged between 1 and 4 per square yard, and the highest count was found in Compartment 4, 70-year-old Scots pine, with 12.8 per square yard.

Inglismaldie Forest, Kincardine. Generally low pupal counts of about 1 per square yard, the highest count being Compartment 5, Scots pine, 31 years old at 2.8.

Montreathmont Forest, Angus. Similar to Inglismaldie, the highest pupal count being in Compartment 60, Scots pine, 27 years old, with 4.4 per square yard.

Tentsmuir Forest, Fife. Conditions of soil and crop would seem to be well suited to Pine Looper, but the pupal count was low, less than 1 per square yard. The highest count, in the southern block of the forest, was found in Compartment 125, Scots pine, 26 years old, at 5 per square yard.

England, North-East Conservancy

Allerston Forest, Yorkshire. Generally low pupal counts of between one and two per square yard were found, the highest being in Compartment 31, Scots pine, 27 years old at 3.8.

Cannock Chase Forest, Staffs. After complete defoliation of between 100 and 150 acres in 1953, complete sampling of all age classes liable to damage was carried out. The defoliated areas are in the south-west and south-east blocks of the forest, which are also the oldest aged crops (Scots pine, 33 and 35 years old). The three classes of defoliation into which the damaged plantations were placed, and the range of pupal counts found in them, were as follows:

Class 1. *Complete defoliation*—150 per square yard and over (the highest individual plot being in Compartment 28 with 634 pupae per square yard.

Class 2. *Severe defoliation*—(Say 50 per cent needle loss). 80 to 150 per square yard.

Class 3. *Slight browning of the Crown*—40 to 80 per square yard.

There was a noticeable graduation from Class 1 defoliation through Class 2 and 3, extending through one or two compartments surrounding the centre of the damaged area. The pupal counts then dropped to 6-20 per square yard, which density can be taken as the general level. Lower counts, of the order of 1 to 2 per square yard, are present in the area extending northwards from the central block, where there are young dense crops of Corsican pine; and there are similar counts recorded in the north-east part of the forest. In the south-east area of defoliation, where the Scots pine is considerably denser, damage is more or less confined to ride sides.

It is quite noticeable that, whereas at Culbin the degree of infestation is very even throughout the crop, at Cannock it varies a good deal within short distances. There are two quite distinct areas of high pupal density including and surrounding the two centres of damage, but these are well separated by much lower counts.

Delamere Forest, Cheshire. A large proportion of the pine here is some 50 or so years old which is a most suitable age for Pine Looper development. The general pupal count was about 3 to 4 per square yard, the highest figure of 7.4 being in Compartment 15, Scots and Corsican pine, planted in 1903. A distinctly lower count was found in Compartments 39 and 24, Scots pine, 28 years old, with 0.8 and 0.6 per square yard, where very damp soil conditions are present.

Bawtry Forest, Notts. Generally low pupal counts of less than 1 per square yard, the highest count being in Compartment 6, Corsican pine, 25 years old, at 1.4.

Peckforton Estate, Cheshire. This private forest of mixed Scots and Corsican pines showed pupal counts of about 2 to 5 per square yard, the highest count being 9.0 in 30-year-old Scots pine, in the south of the main block.

Sherwood Forest, Notts. Mostly Corsican pine with a general low level of pupal counts, about 1 per square yard, the highest count was found in Compartment 20, Scots pine in an old shelter belt, with 3.2.

Clipstone Forest, Notts. Mostly Corsican pine, with some rather poor Scots pine, showing pupal counts between 1 and 6 per square yard. The highest counts were found in an old mixed conifer wood adjoining Compartment 9, in Compartment 47, 27-year-old Corsican pine, and Compartment 67, 26-year-old Corsican pine, which showed from 7 to 9 per square yard.

England, East Conservancy

Bardney Forest, Lincs. Rather young crops of Scots pine with a low pupal density of less than 1 per square yard.

Laughton Forest, Lincs. Mostly Corsican pine with a low pupal density of 1 per square yard or less, the highest count being in Compartment 39, Corsican pine 26 years old, with 2.2.

Tunstall Forest, Suffolk. Generally low pupal counts of less than 1 per square yard, the highest being in Compartments 39 and 37 with 2.8 and 2.2 respectively.

Rendlesham Forest, Suffolk. Generally low counts of between 1 and 3 pupae per square yard, the highest being in Compartment 109, Scots pine, 32 years old. with 5.2.

Thetford Chase Forest, Norfolk and Suffolk. In order to give good coverage over this large but fairly homogeneous area, each beat was sampled at the rate of 10 to 15 per cent of the compartments. Elveden Beat was completely covered. The general count was between 0.1 and 1 pupae per square yard, the highest counts being Cranwich, Compartment 29, Corsican pine, 28 years old and Downham Compartment 50, Scots pine, 27 years old, both with 1.4. The King's Forest and Swaffham Forest nearby were also sampled, and found to have similar populations to Thetford Chase.

England, South-East Conservancy

Alice Holt Forest, Hants. Generally low pupal counts of rather less than 1 per square yard, the highest being in Compartment 49, 64 year-old Scots pine, with 2.5.

Bramshill Forest, Hants. Generally low counts of less than 1 per square yard. the highest being Compartment 34, Scots pine, 30 years old, with 1.4.

Windsor Forest, Berks. This forest, which is administered by the Commissioners of Crown Lands, showed a low count of about 1 per square yard, the highest count made was in the Caesar's Camp area in Scots pine, 49 years old, with 2.4.

New Forest, Hants.

Ringwood. Low pupal counts of less than 1 per square yard, the highest count being in Compartment 2, Scots pine, from 34 to 39 years old, with 0.4.

General

It has been found on the continent that epidemics of *Bupalus piniarius* do not normally come under natural control for three to four years. It is also well known that Scots pine is unlikely to withstand more than one year's complete defoliation. With the population present at Cannock Chase in 1953 and the low percentage of parasitism associated with it, it seemed evident that we must resort to artificial control, if the forest was to be saved. (See Table 58.)

PERCENTAGE OF PINE LOOPER PUPAE PARASITISED AT CANNOCK CHASE, 1953-54
Table 58

Mean pupal counts for Compartments from which pupae are derived. Pupae per square yard.	State of Crop	Percentage of pupae parasitised
238	Defoliated	10.6
285	„	11.9
99	Slightly defoliated	16.2
88	„	20.0
9	Undamaged	19.8
38	„	33.5

It is interesting to note that lower percentage parasitism was found in high infestation areas. This suggested that so far the rate of pine looper increase had outstripped that of the parasites involved. As the most numerous parasite concerned, *Cratichneumon nigritarius* Grav., attacks fifth instar larvae, it is certain that no natural control of the infestation could be expected from it before the end of the larval feeding period in the summer of 1954—at the very earliest.

It has, therefore, been decided to treat both Cannock Chase and Culbin Forests with insecticides. On the dry Culbin sand dunes, the trees are so near the margin of subsistence as it is, that they might well be expected to suffer more severely as a result of defoliation than would pine growing on more normal soils; control measures are to be taken in this forest for that reason. In July or August 1954, depending on the development of the insect outbreaks in that year, it is proposed to spray about 2,500 acres at Cannock and 3,500 acres at Culbin with a suitable formulation of D.D.T. applied from aircraft.

This operation will aim primarily at a control of *Bupalus piniarius*, but will also provide a most interesting trial of a modern insecticide against this pest. It will also be the first experience of aerial applications of insecticides to forest areas made in this country.

FOREST INSECTS IN THE GALE-DAMAGED WOODLANDS OF NORTH-EAST SCOTLAND, 1953-1954

By Dr. M. CROOKE,
Forest Entomologist

Introductory

THE gale of the 31st January, 1953, caused widespread devastation in the forests of North-east Scotland, where it was estimated that about 40 million cubic feet of timber was blown down, in scattered blocks covering 10,000 acres, dispersed over parts of eight counties. In this important pine-growing district, the majority of the crops damaged were of Scots pine and, in general, older woodlands suffered most, while younger crops under about forty feet in height were but little damaged. Most of the damage was located, therefore, on private estates whose woodlands are in general older than those on Forestry Commission areas. It soon became known that clearance of this relatively vast amount of timber would take approximately two years.

The entomological implications of the disaster and of the probable schedule of clearance at once became clear. With the preponderance of Scots pine in the blown areas, coupled with the fact that much of the material would still be on the ground in 1954, and perhaps even later, it was obvious that even although efforts were to be made to extract the pine first, a very large reservoir of breeding material for a variety of injurious forest insects had been established, and would be present for some time. The species most to be feared was undoubtedly *Myelophilus piniperda* L. which is capable of attaining very high population levels in a short time in such damaged woodlands, and which can inflict serious and permanent damage to younger standing plantations of pine when these are close to the breeding centres. Accordingly, plans were made for an observational study in the blown areas, to be devoted primarily to *Myelophilus* development but also to include that of other insect species. This was essential to provide both a comprehensive record of the situation, and also a basis for any proposed control measures, even although in the early days the possibility of employing any practicable controls appeared remote.

Methods of Survey

The survey ran continuously from 1st May until the end of September. Initially, and with the ready consent of the woodland owners concerned, thirty-three sample areas, all on private estates, were selected. The selection was made on purely theoretical grounds and without previous examination of the areas; the samples selected conformed to the following conditions:

(i) They gave a good geographical coverage of the parts of the country affected by the gale.

(ii) Each was in a pure pine or predominantly pine crop.

(iii) Each was of considerable acreage (the average was 163 acres).

(iv) Each constituted a breeding centre which threatened nearby standing pine crops.

These sample areas were visited in rotation and about one day spent in each: they were so examined four times during the season. The theoretical basis of sampling was as follows:

(i) The number of trees examined on each sample area per visit was ten (reduced to five or eight on a few of the smallest samples).

(ii) The sample trees were spaced equidistantly along the longest axis through the blown woodland, the first sample tree being sited on or near the margin of the blow.

(iii) Each sample tree was subsampled by removing, from the stem, rings of bark one foot in length at heights of 5, 10, 20 and 40 feet from base of stem.

(iv) As an index of pine shoot beetle population, the number of mother galleries per one foot ring of bark and timber so exposed was counted. Since these galleries run longitudinally along the stem and may, therefore, be either totally or partially within the ring sample, the index was computed as the number of galleries lying wholly within the ring, plus half the number of galleries lying in part beneath the sampled bark and in part beneath the unsampled bark. This is the "normal sample".

(v) As an index of brood numbers per mother gallery, the total number of broods per sampled ring was counted on every fifth tree. This is the "intensive sample".

(vi) Samples of the brood were sent in to the laboratory to assess their stages of development; and any predators or other bark beetles found also sent in for determination.

The following amendments of the technique were found to be desirable and were later incorporated:

(i) In addition to sampling ten "blown whole" trees, that is trees blown over without breakage of the stem (two of which were intensively sampled), two snapped stems were intensively sampled at each visit. This became a regular feature of sampling from 26th June onwards, although before this date random counts and observations had been made on snapped stems. In addition, the percentage of snapped stems out of the total was estimated.

(ii) Examinations were made of the thinner-barked portions of the stems above the fixed sample rings, to collect information on other bark beetles such as *Ips acuminatus* Gyll. and *Pityogenes* spp.

Results of the Survey

Rate of Multiplication of Myelophilus. A number of observations showed that *Myelophilus* had commenced tunnel-cutting and ovipositing long before the survey commenced on 1st May. The first record of egg-laying was at Crathes on March 6th, but it is probable that the beetles were active even before that early date. With this early start, due to the warm spring in the district, the main risk was that *Myelophilus* would be able to complete two broods in the season. The summer, however, proved to be neither exceptionally hot nor dry—the conditions which would have favoured an acceleration in beetle development and production—and there is no doubt that no second brood was completed, although it was commenced in some localities.

When the survey began, therefore, some mother galleries had been completed and the first larvae hatched, whilst many other mother galleries were well advanced and contained eggs. Fresh tunnel-cutting continued from this date throughout the season, the later attempts being made by individuals which had bred early, fed, and returned to breed again. From the types of log on which beetle development was able to proceed (a point of major importance which will be dealt with below) the first adults of the new brood started to emerge in late June and early July. The period of emergence proved to be a protracted one and fresh adults were appearing from late June until the end of the season.

Numbers Breeding, and breeding sites of Myelophilus. The results of the survey showed clearly that *Myelophilus* was successful in breeding in appreciable numbers only in stems which had been snapped by the gale, or in stems which had been removed from the root. In general, trees which had been "blown whole", and which retained some roothold, remained alive during the summer and resisted beetle colonisation. For trees which had been "blown whole", the mean number of mother galleries per tree, taking the survey overall, was 0.33, with a range of from 0.00 to 1.82 per tree by sample areas; for snapped stems, the comparative figure was 5.52, with a range of from 1.58 to 15.75. These figures do not, of course, represent the true number of mother galleries per tree but only those discovered by ring sampling. The true figure can be roughly obtained by multiplying the above figures by about ten. Although subject to wide variation, the mean number of brood produced per mother gallery was 22.7 ranging from 11.6 to 40.3.

The relative moisture content of the different types of tree was considered to be of importance in determining whether or not beetle invasion was successful, and this was therefore tested by removing radial cores 90 mm. long by 6 mm. in diameter from stems of the different types, and determining their moisture contents. All samples were collected in September from an area of about half an acre in a blown pine wood of about forty years of age on the Dunecht Estate, Aberdeenshire. The results are summarised in Table 59 below.

DETAILS OF SAMPLES OF BLOWN TREES FROM THE DUNECHT ESTATE

Table 59

Number of stems sample	Type of Stem	Number of samples per stem	Situation of samples	Range of Moisture Content percentage per stem	Mean Moisture Content percentage	Breeding *Myelophilus* or Not.
9	Standing undamaged	4	N, S, E, W at 5 feet above base	45.8–79.9	63.7	Not breeding
10	Blown whole	3	Top, side, at 5 feet from base	50.2–81.0	61.8	Not breeding
11	Snapped, basal standing portion	4	N, S, E, W at 5 feet above base	72.5–113.0	90.7	Breeding
10	Snapped, upper portion above break	3	Top, side, at 5 feet from base	27.6–45.8	37.9	Breeding

Thus, *Myelophilus* breeding was proceeding in parts of stems with both a significantly higher and significantly lower moisture content than that which could be regarded as normal (i.e. undamaged standing trees); whilst "blown whole" stems had a moisture content closely approximating to that of the standing trees and were, like the standing trees, resisting beetle invasion. The relative resistance of the stems to beetle colonisation is determined, therefore, not by moisture content alone or primarily but more probably by the osmotic pressure of the sap and, in particular, by the tree's ability to produce resin flow in response to wounding. The beetles made many attempts to enter "blown whole" stems but most of them were dissuaded by the resin flow, or trapped and killed in it. On the other hand, resin flow after boring in snapped stems was negligible. The fact that some breeding was possible in "blown whole" stems was governed, in part, by the extent of roothold retained by the tree; when the root system was completely or almost severed from the soil, the stem was weakened sufficiently to allow the entry of the beetle.

To sum up, it can be said that the total number of *Myelophilus* breeding in the gale-damaged woodlands was much lower than was initially feared, because:

(i) That the vast majority of the "blown whole" stems resisted beetle invasion.

(ii) That the weather during the season was directly unfavourable to beetle development and that, indirectly, by helping to keep many of the blown trees alive, it further hampered beetle production.

(iii) That the endemic population prior to the gale was apparently a low one.

Predators of Myelophilus. Insect predators were not numerous during this first season. The following species were recorded: *Thanasimus formicarius* L.; *Dromius quadrinotatus* Panz.; *D. meridionalis*, Dej. and *Rhizophagus depressus* F.

Woodpeckers in some localities were responsible for destroying broods of pine shoot beetle.

Other Bark Beetle Species on Pine. *Myelophilus minor* Htg. was recorded in small numbers from eight of the sample areas. *Pityogenes bidentatus* Herb. and *P. quadridens* Htg. were abundant in all localities, breeding in the thinner-barked portions of the stems, whilst *Ips acuminatus* Gyll. and *Hylurgops palliatus* Gyll. were widespread but less numerous. Reference to *Hylastes* spp. will be found later.

Possibilities of Control of Myelophilus

Snapped Trees. Snapped trees acted, in effect, as trap stems, and it would have been of the utmost value if they could have been extracted or peeled on site before the young beetles commenced to emerge. They had "soaked up" much of the original beetle population, and their disposal would have helped materially to keep the beetle density at a reasonably low level for another season. This was, of course, a counsel of perfection, and woodland owners, burdened with worries of more immediate urgency, were understandably but unfortunately nowhere able to put it into effect.

Timber Stacks. Apart from snapped trees the only other major breeding site was in felled timber, and where this had been collected into stacks, there appeared to be some possibility of attacking the beetle with insecticidal sprays. Previous work in other countries has shown that bark beetles can be deterred from entering bark to breed by the application of either DDT or BHC at a concentration of about 0.5 per cent, and a rate of application of about one gallon per hundred square feet of bark surface. It seemed at least feasible that more concentrated sprays of these insecticides, applied to timber already infested, might persist long enough and be toxic enough to prove fatal to young beetles emerging through the treated bark. Accordingly, a spraying unit was fitted on a Land Rover, so that experiment and field trials on a larger scale could be carried out.

Experimental Spraying at Speymouth Forest, Morayshire. Sixteen stacks of pitprops, heavily infested with *M. piniperda*, were sprayed with DDT or BHC at varying concentrations and differing rates of application, and the results of the treatments assessed in the laboratory. Spraying was carried out on June 2nd, samples were removed to the laboratory on June 26th, and beetles commenced to emerge in early July. Results appear in Table 60 below. An unexpected result was the effect of the treatments upon the immature stages of the beetle prior to emergence, which is clearly reflected in the number of adults produced per mother gallery from the treated stems as compared with those from the untreated controls.

Mortalities produced by all treatments are reasonably satisfactory, although those produced by BHC are uniformly lower than those produced by DDT, with the exception of Gamalin (a very concentrated α BHC preparation in oil). This is particularly evident in the poor pre-emergence kill obtained for lots 7, 8 and 9. The BHC suspensions were obtained by using a 50 per cent dispersable powder, and these tended to sediment out badly in the tank, and to clog the filters and jets. Thus the physical characteristics of the preparation employed may account for the poorer results obtained with BHC. In all cases the DDT emulsions were prepared from a 25 per cent solution in oil.

EFFECTS OF SPRAYING PITPROPS AT SPEYMOUTH FOREST

Table 60

Lot Number	Treatment: Insecticide	Treatment: Concentration	Treatment: Rate of application	Number of adults produced per mother gallery	Per cent beetles dead four days after emergence	Theoretical percentage mortality due to treatment
1	DDT	0.5%	1 gal./100 sq. ft.	4.2	69.8	90.4
2	,,	,,	2 gal./100 sq. ft.	3.3	63.3	91.8
3	,,	1.0%	1 gal./100 sq. ft.	3.6	69.0	92.7
4	,,	,,	2 gal./100 sq. ft.	4.0	70.9	92.6
5	,,	3.0%	1 gal./100 sq. ft.	1.3	83.2	98.9
6	,,	,,	2 gal./100 sq. ft.	2.4	71.1	95.6
7	BHC	0.5%	1 gal./100 sq. ft.	11.7	67.0	74.5
8	,,	,,	2 gal./100 sq. ft.	9.0	68.3	81.3
9	,,	1.0%	1 gal./100 sq. ft.	8.4	65.2	80.4
10	,,	,,	2 gal./100 sq. ft.	(Samples	lost)	
11	,,	3.0%	1 gal./100 sq. ft.	3.6	70.1	93.1
12	,,	,,	2 gal./100 sq. ft.	5.3	67.6	88.7
13	Gamalin	1pt. in 20 gals.	1 gal./100 sq. ft.	1.5	68.7	97.0
14	control: no treatment	—	—	23.0		—
15		—	—	20.7 } Av. = 16.8	} Av. = 21.5	—
16	,,	—	—	11.7		—

Field Trials of Stack Spraying. Before the results of these experiments were known, field trials on a larger scale were carried out at five Forestry Commission forests where a total of approximately 65,000 cubic feet of timber was treated. In every case the treatment applied was 2 per cent DDT at the rate of one gallon per 100 square feet of bark surface. DDT was selected for this work because, being in oil solution, it was much easier to handle than the BHC dispersable powder, and because of its superior residual effect. Laboratory assessments were carried out on samples as for the Speymouth experiment, and the results shown in Table 61 obtained.

RESULTS OF LARGE-SCALE STACK SPRAYING TRIALS

Table 61

Forest	Date of Treatment	Number of Adults produced per Mother Gallery		Per cent Beetles dead four days after Emergence		Theoretical percentage mortality due to treatment
		Treated	Control	Treated	Control	
Countesswells....	4th July	5.8	14.0	52.2	20.0	75.3
Midmar	7th-8th July	2.6	16.2	90.8	20.0	98.2
Speymouth	9th-11th July	5.8	23.0	99.0	61.0	99.4
Monaughty	16th July	5.5	18.9	82.5	45.9	90.6
Culbin	18th-21st July	4.6	12.2	71.8	20.5	86.6

Example of Calculation of Theoretical Percentage Mortality (for Countesswells, above). If 100 beetles in young stages are present in a treated log only $\frac{100\times 5.8}{14}=41.4$ beetles will emerge, of these 41.4 beetles, $\frac{(41.4\times .522-.200)}{(1-.200)}=16.7$ will be dead *as a result of treatment*, four days after they have emerged. $\therefore$ 41.4—16.7=24.7 beetles remain alive $\therefore$ mortality=75.3 per cent.

It will be noted that the above treatments were applied at the time when the first fresh adults were emerging and field records noted that "young *M. piniperda* beetles were emerging as spraying was being done and these, together with old *M. piniperda* and weevils, were obviously being affected".

It seems clear from the results of the Speymouth experiment and the later field trials that stack spraying against *Myelophilus* can be, at least, fairly effective.

It is justifiable to use this method of control, however, only where the following conditions hold:

(i) That the logs are heavily infested.

(ii) That the majority of the population beneath the bark is nearing maturity.

(iii) That nearby pine plantations are threatened by the emerging broods.

(iv) That it is impossible to remove the stack before the main emergence period.

Before the results of these trials were known, the Forestry Commission on the 1st June offered to make available to owners a free stack-spraying service against pine shoot beetle for the remainder of the season, but the response was disappointing. Three enquiries were received but, on investigation, none of the cases merited action and no spraying was carried out, therefore, on private estates.

Pine Weevil and Hylastes Bark Beetles. A brief survey, covering nine forests distributed throughout the gale-damaged area, was carried out in October 1953 to determine the extent and rate of development of both *Hylobius abietis* L. and *Hylastes spp.* These insects will not, of course, become of major importance until the restocking of the devastated woodlands is started; but it was nevertheless considered advisable to collect data on these points so that tentative forecasts of the probable course of events could be made. The survey showed that:

(i) No *Hylobius* or *Hylastes* breeding was taking place in stumps from which the stem had not or had only very recently been removed.

(ii) In stumps felled in the earlier part of 1953 both insects were breeding in considerable numbers.

In the latter case colonisation had been more rapid than would have occurred in stumps of normally felled trees, and the rate of development had also been rapid. A high proportion of *Hylobius* were, by October, mature larvae ready to pupate. The relatively rapid development seems to be attributable to the acceleration on the drying-out of the root systems through disturbance, and it appears probable that this in turn will quickly exhaust the breeding sites so that a sharp, but short, epidemic of *Hylobius* and *Hylastes* can be anticipated.

DEVELOPMENT OF TRACTORS FOR OPERATION ON SOFT GROUND

By R. G. SHAW,
Machinery Development Officer

MUCH of the land now becoming available for afforestation in Great Britain offers conditions which are too severe for the use of tractors designed to haul machinery under the normal conditions of agriculture. One of the most difficult problems is crossing soft peat which, if adequately drained, in many cases offer suitable planting ground for certain trees. Much progress has been made in the development of drainage ploughs in recent years, and the Cuthbertson plough is already in wide use, but standard track-laying agricultural tractors are quite unable to pull these ploughs on very soft ground. Although in many cases they possess adequate power, they are unable to apply it because track slip occurs before a sufficient drawbar pull has been reached.

An investigation has been undertaken with a view to developing a tractor which, whilst being able to give a sufficient drawbar pull on soft ground, is not too expensive in first cost and subsequent maintenance. To do this meant using a standard basic tractor and introducing such alterations as would give it the desired performance. The new Fordson Major was taken as the starting point as it is already available in tracked form as the County tractor.

The next step was to decide what action must be taken to reach the required soft ground performance. Much information was already available from the development of tracked machines during and since the 1939-45 war, and it was known that it would be necessary to reduce the average track ground pressure to something around 2.5 lb. per sq. in. The fact that the ground pressure on the County tractor is 4 lb. per sq. in. on the widest standard tracks (16 inches) showed that a major modification would be required.

It must be mentioned here that the figure commonly used for quoting ground pressure on tractors assumes that the weight of the tractor is divided evenly over the area of the track in contact with the ground. This condition does not exist in practice since, even if the weight on the load-carrying track rollers is equal, each roller will concentrate the load on the track at its point of contact. Consequently a flexible track running under a number of rollers will, in fact, exert a very much higher pressure on the ground at these points of contact than it does elsewhere. The greater the number of suspension points the better will be the weight distribution.

An equally important point to be taken into account in considering distribution of weight is the effect of the drawbar pull which is being exercised by the tractor at any time.

In the case of a tractor, which when stationary, carries its weight evenly distributed over its bogie wheels, the centre of gravity will be over the mid-point measured along the length of track on the ground. However, when the tractor exerts a drawbar pull on an implement, a new force is introduced which entirely alters the distribution of weight as shown in Fig. 17.

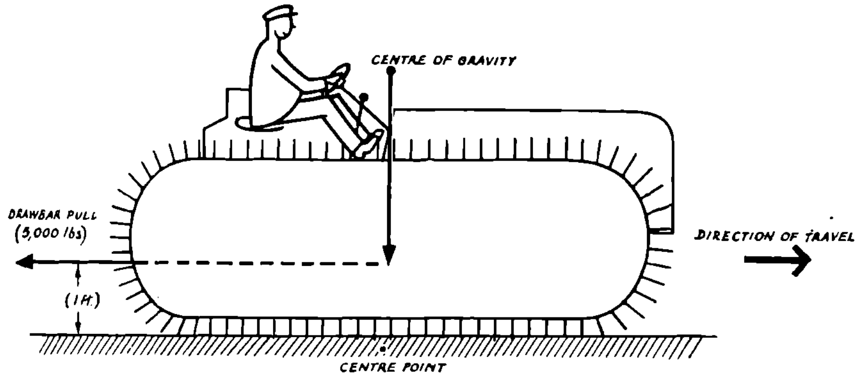


Fig. 17. Effect of drawbar pull on the weight distribution of a Crawler Tractor drawing an implement.

If in this instance the drawbar pull is 5,000 lb., and the drawbar is one foot above the ground, there is a force of 5,000 lb. ft. transferring weight off the front half of the track on to the rear half, so that the distribution of weight is entirely upset and most of the weight of the tractor is being carried on the rear track rollers. Thus the ground pressure of the track under these rollers will be very much higher than it was before the drawbar pull was applied. It is this very fact which causes the failure of so many agricultural tractors when attempting to give heavy drawbar pulls on soft ground. What happens is that since the front part of the track carries no weight, that area of track is not contributing anything to forward propulsion. Whilst this is happening the rear end of the track carries all the weight, so it breaks through the ground surface and loses its grip, in the mud below.

The only way that this uneven weight distribution under load can be eliminated is by building the tractor with the centre of gravity well forward of the centre point. In the diagram above if the tractor weighed 10,000 lb. it would be necessary to move the centre of gravity six inches forward to provide a force of 5,000 lb. ft. to counteract the force set up by the drawbar. This would of course mean that when no drawbar pull was applied the tractor would be out of balance (front heavy). In considering only the soft ground ploughing performance of a tractor some front heaviness when not under load would be acceptable in order to get even weight distribution when the load is applied, since it is then that the whole of the length of track is needed to contribute its share of grip on the ground. The majority of tractors are, however, built for the dual purpose of agricultural and industrial usage. In the latter case heavy weights such as bulldozers are attached to their front end and to offset this the centre of gravity of the tractor would need to be behind the centre point—the direct opposite to the agricultural requirement. To meet these conflicting interests most manufacturers compromise by positioning their centre of gravity about the centre point.

In setting out to modify a Fordson County tractor to get the maximum drawbar performance on very soft ground, it will be appreciated that the two main aims were:

(*a*) To get the maximum area of track on the ground.

(*b*) To position the centre of gravity far enough forward to balance the tractor under load.

Fortunately the Fordson County is easy to convert to wide gauge by increasing the distance between the track centres. This was done by inverting the sprocket discs and fitting a longer suspension spring and longer radius rods. With this alteration it was possible to fit track plates thirty inches wide on the existing track chains.

Modified in this way at a cost of little more than £100, one machine has been submitted to field trials, and has completed over 500 hours running, with only one weakness being revealed on the modified track and suspension.

It was quickly established that the soft ground performance of the tractor had been greatly increased, so it was decided to take the experiment a stage further on another machine and not only widen but also lengthen the tractor (see Photos. 10 and 11). This was done by inserting an extra transmission case between the gearbox and final drive, with the necessary shaft to carry the drive through.

The suspension frames were lengthened to take nine load-carrying track rollers instead of the standard five, and so the multi-point suspension mentioned as so desirable earlier in this paper was in fact achieved. On the completed machine the centre of gravity is two inches forward of the centre point, which is not quite as far forward as is theoretically desirable. The weight has been increased from four tons to six tons and the ground pressure works out at 2.8 lb. per square inch.

At the time of writing this paper this new machine is still regarded as being in the experimental stage, but the performance is very promising. The simple expedient of fitting thirty-inch track plates on the standard track chains has been suspect from the start of the experiment, owing to the enormous overhang incurred; but the first prototype completed 500 hours without track trouble. This modified version of the County tractor is, of course, intended only for use on soft ground, and the track would not be expected to survive under hard ground conditions. The field trial stage will continue for several months to test both the performance of the machine under all soft ground conditions and also the mechanical reliability of the many new features that have been introduced.

APPENDIX I

LIST OF THE MAIN EXPERIMENTAL PROJECTS AND THE LOCALITIES WHERE WORK ON THEM IS CONCENTRATED

WHILE most of the investigations and experiments of the Research Branch are scattered throughout forests and on private estates all over the country, there are certain areas where work on some projects is more or less concentrated. These are briefly given below:

NURSERY EXPERIMENTS. Including partial sterilisation of the soil, maintenance of fertility, compost and fertiliser experiments, green cropping, chemical weed control, etc.
In England —Kennington Nursery near Oxford.
Sugar Hill Nursery in Wareham Forest (Dorset).
In Scotland —Tulliallan and Devilla Nurseries (Fife).
Newton Nursery (Morayshire).

PLANTING EXPERIMENTS ON PEAT. Kielder Forest (Northumberland).
Clocaenog Forest (Denbighshire).
Beddgelert Forest (Caernarvonshire).
Inchnacardoch Forest (Inverness-shire).
Achnashellach Forest (Ross-shire).

PLANTING EXPERIMENTS ON HEATHLAND. Wareham Forest (Dorset).
Wykeham and Broxa in Allerston Forest (Yorkshire).
Harwood Dale in Langdale Forest (Yorkshire).
Teindland Forest (Morayshire).
Clashindarroch Forest (Aberdeenshire).

PLANTING EXPERIMENTS ON CHALK DOWNLAND. Queen Elizabeth Forest (Buriton) (Hants. and Sussex).
Friston Forest (Sussex).

ESTABLISHMENT OF OAK. Forest of Dean (Gloucester, Hereford and Monmouth).
Dymock (Gloucester and Hereford).
Tintern Forest (Monmouth).

POPLAR TRIALS. Harling, Thetford Forest (Norfolk).
Hockham, Thetford Forest (Norfolk).
Yardley Chase (Beds. and Northants.).

SPECIES PLOTS OR "FOREST GARDENS". Bedgebury Forest (Kent).
Thetford Forest (Norfolk).
Beddgelert Forest (Caernarvonshire).
Benmore Forest (Argyll).

GENETICS WORK. Grafting, propagating, etc.—Alice Holt Forest (Hants.).
Grizedale Forest (Lancashire).

APPENDIX II

STAFF OF THE RESEARCH BRANCH OF THE FORESTRY COMMISSION AS AT 31st MARCH, 1954

DIRECTORATE OF RESEARCH AND EDUCATION: 25, Savile Row, London, W.1.
Tel.: Regent 0221.

J. Macdonald, C.B.E.	Director
Miss A. Brooks, M.B.E.	Senior Executive Officer

UTILISATION DEVELOPMENT

E. G. Richards, M.C., B.Sc.	Divisional Officer
J. R. Aaron, M.A.	District Officer

MACHINERY

R. G. Shaw, B.A., A.M.I.Mech.E.	Machinery Research Officer

FOREST RESEARCH STATION: Alice Holt Lodge, Wrecclesham, Farnham, Surrey.
Tel.: Bentley 2255.

M. V. Laurie, O.B.E., M.A., Dip.For.	Conservator, Chief Research Officer
E. C. Harper	Higher Executive Officer

SILVICULTURE (SOUTH) SECTION (Alice Holt)

R. F. Wood, B.A., B.Sc.	Divisional Officer
J. M. B. Brown, B.Sc., Dip.For.	District Officer
M. Nimmo	,, ,,
G. D. Holmes, B.Sc.	,, ,,
A. D. S. Miller, B.Sc.	,, ,,
J. Jobling, B.Sc.	,, ,,
J. R. Aldhous, B.Sc.	,, ,,
G. Buszewicz, Mgr.Ing.	Experimental Officer

SILVICULTURE (NORTH) SECTION: Govt. Buildings, Bankhead Avenue, Edinburgh, 11.

M. V. Edwards, B.A.	Divisional Officer
J. W. L. Zehetmayr, B.A.	District Officer
R. Faulkner, B.Sc.	,, ,,
R. Lines, B.Sc.	,, ,,

MENSURATION AND CENSUS SECTIONS (Alice Holt)

F. C. Hummel, M.A., D.Phil.	Divisional Officer
A. M. Mackenzie	District Officer
G. M. L. Locke, B.Sc.	,, ,,
J. N. R. Jeffers	

FOREST PATHOLOGY SECTION (Alice Holt)

T. R. Peace, M.A.	Divisional Officer
J. S. Murray, B.Sc.	District Officer
S. Batko, D.Ing.	

FOREST ENTOMOLOGY SECTION (Alice Holt)

M. Crooke, B.Sc., Ph.D.	District Officer
D. Bevan, B.Sc.	,, ,,
Miss J. Davies, B.Sc.	Experimental Officer

FOREST GENETICS SECTION (Alice Holt)

J. D. Matthews, B.Sc.	District Officer
A. F. Mitchell, B.A., B.Agr.	,, ,,

DOCUMENTATION AND PHOTOGRAPHY SECTION (Alice Holt)

G. D. Kitchingman, B.A., Dip.For.	District Officer
I. A. Anderson	Senior Photographer
Miss T. K. Wood	Photographer

APPENDIX III

PUBLICATIONS BY MEMBERS OF THE RESEARCH BRANCH STAFF

during year ended 31st March, 1954

The following papers by members of the Research Branch staff were published during the year ended 31st March, 1954:

AARON, J. R. — Use of Home Grown Timber in Wood Turning and Related Trades in Scotland in 1953. Forest Record No. 27, H.M.S.O. (1954).

BARTLETT, G. — A Caithness Forestry Experiment.
Scottish Agriculture, Vol. 33, No. 1, pp. 33-35 (1953).

BROWN, J. M. B. — The Rhododendron Problem in the Woodlands of Southern England.
Quarterly Journal of Forestry, Vol. 47, No. 4, pp. 239-253 (1953).
Forestry Practice in Britain:
Soils and Climatic Conditions.
Wood (December 1953), pp. 472-475.

CROOKE, MYLES — An Outbreak of the Pine Looper Moth, *Bupalus piniarius* L., at Cannock Chase in Staffordshire, and some notes on the Biology of this Pest.
Quarterly Journal of Forestry, Vol. 48, No. 1, pp. 36-38 (1954). Also in *Journal of Land Agents Society*, Vol. 53, pp. 26-28. (1954), and *Irish Forestry*, Vol. 10, No. 2, p. 60 (1953).

EDWARDS, M. V. — Frost Damage to Sitka Spruce Plants in the Nursery and its Relation to Seed Origin.
Scottish Forestry, Vol. 7, No. 2, p. 51 (1953).
Scottish Studies of the Provenance of European Larch.
Proceedings of the Congress of the International Union of Forest Research Organisations, Rome, 1953. (*In the press.*)

FAULKNER, R. — Notes on Choosing a Suitable Conifer Seedbed Cover.
Scottish Forestry, Vol. 7, No. 4, pp. 121-124 (1953).

HOLMES, G. D. — Forestry Practice in Britain:
Seed and Nursery.
Wood (February 1954), pp. 81-84.
Recent Developments in the Control of Weeds in Forest Nurseries.
Proc. Brit. Weed Cont. Conf., 1953, pp. 282-288.
The Chemical Control of Calluna vulgaris Salisb.
Proc. Brit. Weed Cont. Conf., 1953, pp. 289-296.

HUMMEL, F. C. — The Definition of Thinning Treatments.
Proc. Cong. Int. Union For. Res. Organ., Rome, 1953. (*In the press*).

HUMMEL, F. C. AND CHRISTIE, J. — *Revised Yield Tables for Conifers in Great Britain.*
Forest Record No. 24, H.M.S.O. (1953).

JEFFERS, J. N. R. — Statistical Methods in Forest Research.
Proc. Cong. Int. Union For. Res. Organ., Rome, 1953. (*In the press*).

KITCHINGMAN, G. D. — The Literature of British Silviculture.
Quarterly Journal of Forestry, Vol. 47, No. 4, pp. 254-262 (1953).

APPENDIX III—continued.

LINES, R. — The Scottish Gale Damage.
Irish Forestry, Vol. 10, No. 1, pp. 3-15 (1953).

MACDONALD, JAMES — Recent Developments in Forest Nursery Practice in Great Britain.
Quarterly Journal of Forestry, Vol. 47, No. 2, pp. 89-100 (1953).

MATTHEWS, J. D. — Forest Tree Breeding in Britain.
Zeitschrift fur Forstgenetik und Forstpflanzenzuchtung, Vol. 2, No. 3, pp. 59-65 (1953).
Japanese Larches at Dunkeld, Perthshire.
Forest Record No. 25, H.M.S.O. (1954).

MILLER, A. D. — Factors Affecting the Growth and Form of Young Beech at Gardiner Forest, Wiltshire.
Forestry, Vol. 26, No. 2, pp. 111-122 (1953).

MURRAY, J. S. — A Note on the Outbreak of *Chrysomyxa abietis* Unger (Spruce needle rust) in Scotland, 1951.
Scottish Forestry, Vol. 7, No. 2 (1953), pp. 52-56.
Group Dying of Spruce in Eire.
Irish Forestry, Vol. 10, No. 2, pp. 55-57 (1953).
Two Diseases of Spruce under Investigation in Great Britain.
Forestry, Vol. 27, No. 1, pp. 54-62 (1954).

PEACE, T. R. — Testing of Trees for Resistance to Disease.
Proc. Cong. Int. Union For. Res. Organ., Rome, 1953. (*In the press.*)
International Code of Nomenclature for Cultivated Plants.
Report of the Seventh Session of the International Poplar Commission, F.A.O., Rome, 1954, Annex 6, p. 39 (1954).
Experiments on Spraying with DDT to Prevent the Feeding of *Scolytus* Beetles on Elm and Consequent Infection with *Ceratostomella ulmi.*
Annuals of Applied Biology, Vol. 41, No. 1, pp. 155-164, March, 1954.

REYNOLDS, L. — *Manufacture of Wood Charcoal in Great Britain.*
Forest Record No. 19, H.M.S.O. (1953).
Use and Manufacture of Wood Flour.
Forest Record No. 21, H.M.S.O. (1953).

RICHARDS, E. G. — Wood Waste Utilisation in Germany.
Scottish Forestry, Vol. 7, No. 4, pp. 118-120 (1953).

SHAW, R. G. — *Use of Chutes for Extraction of Thinnings.*
Forest Record No. 20, H.M.S.O. (1953).

WEATHERELL, J. — *Forest Fire Caused by Lightning.*
Quarterly Journal of Forestry, Vol. 47, No. 3, pp. 202-203 (1953).
Heathland Afforestation in the Scarborough District.
The Natural History of the Scarborough District, pp. 286-296 (1953).

WOOD, R. F. — Forestry Practice in Britain:
Species Planting Methods and Spacing.
Wood (March 1954), pp. 120-123.

ZEHETMAYR, J. W. L. — Experimental Plantations in the far North of Scotland.
Scottish Forestry, Vol. 7, No. 3, p. 71 (1953).
Skogsgödsling i Storbritannien (Forest Manuring in Great Britain).
Växt-närings-Nytt, Vol. 10, No. 2, pp. 31-36 (1954).
Experiments in the Economics of Brashing.
Proc. Cong. Int. Union For. Res. Organ., Rome, 1953. (*In the press.*)

Other Forestry Commission Publications prepared by Members of the Research Branch Staff were:—

FORESTRY COMMISSION CENSUS REPORTS

No. 2. *Hedgerow and Park Timber and Woods under Five Acres,* 1951.
H.M.S.O., 1953.

No. 3. *Welsh County Details.*
H.M.S.O., 1953.

No. 4. *Scottish County Details.*
H.M.S.O., 1953.

No. 5. *English County Details.*
H.M.S.O., 1953.

FORESTRY COMMISSION LEAFLET

No. 30. *Sooty Bark Disease of Sycamore.*
H.M.S.O., 1952.

Printed in Great Britain under the authority of Her Majesty's Stationery Office
by Joseph Wones Ltd., West Bromwich

(2710)_Wt. 4500/2161 K20 5/55 J.W.Ltd. Gp. 517

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDED MARCH 1955

LONDON
HER MAJESTY'S STATIONERY OFFICE
1956

CONTENTS

PART III

REPORTS ON RESULTS OF INDIVIDUAL INVESTIGATIONS

APPENDICES

INTRODUCTION

By JAMES MACDONALD

DURING the year, the work of the Research Branch continued to develop mainly along the lines which have been followed for the past four years but, nevertheless, a change in emphasis is gradually taking place because the problems of establishing forests, with which we have been for so long occupied, are slowly becoming less prominent as problems of maintenance, protection, management and utilisation rise in importance and urgency. This change was foreseen some time ago and, during recent years, substantial progress has been made in collecting basic information on which subsequent studies in these subjects can be founded. It is certain that more will be heard of these aspects of forest research in years to come, and less, relatively, of the hitherto familiar problems of the first stages of afforestation.

There yet remain several types of land on which research must be prosecuted with vigour because we have not been able, so far, to obtain assurance that crops can be satisfactorily established and made to grow to reasonable dimensions.

The poor *Scirpus* peats of the north and the north-west of Scotland are an example. When exposure is not too severe, it has been possible, with intensive drainage and turf planting combined with applications of phosphate at planting, to establish plantations successfully and bring them to the stage of canopy formation. Whether they continue to grow after this stage has been reached, without further treatment of a special kind, would seem to depend very much on the initiation of a nutrient cycle in which nutrients taken from the soil are returned through the fall of branches and needles; and also, to some extent, on changes in the physical character of the peat, brought about by the growth of the trees. Because we now have a small number of plantations at this stage, with fully documented histories, it is possible to find out what changes are taking place, and we have been fortunate in enlisting the help of the staff of the Macaulay Institute for Soil Research, Aberdeen, where the necessary work will be carried out.

Where, to poor soil conditions, there is added the effect of severe exposure, we are continuing, by the use of pilot plantations, to study the behaviour of various species of tree. Work of this kind has been expanded considerably in the last few years.

Another type of land which has received much more attention recently is the ground which lies above our present planting line. Here the problem is to find out whether it is possible to go higher with planting and yet obtain a crop which is worth producing and, if it is possible, to attempt to fix new and higher limits. If this attempt were successful, it would bring into production considerable areas which, at present, are little used.

Another class of land which presents special problems is that in the southern Pennine country where, added to high elevation, exposure, and relatively poor soils there is the extra adverse factor of heavy atmospheric pollution. Some years ago, a few pilot plantations were laid down in the hill country above Halifax in Yorkshire, and it is clear, from the performance of the trees, that much further detailed work must be done in order to disentangle the effects of the various injurious influences.

Of a different character are the problems posed by the derelict broadleaved woodlands, of which there are such large areas in the southern half of Great Britain, and of which the restoration to full production is a matter of some urgency. We know that trees, often of large size, can be grown on these sites; the problem is to stock them again with the species we want, at a reasonable cost. Thus, in the work which has been carried out in this field, particular attention has been paid to the costs of operations and to the returns from sales of produce; and in future investigations the economics of restocking will be carefully studied. The disappearance of rabbits, or the reduction in their numbers, caused by myxomatosis, may alter the picture to some extent by eliminating the need for fencing. On the other hand it may lead to the growth of undesirable and unwanted tree and shrub species.

Field experimenting in agriculture has a great advantage in that it is dealing mainly with annual or biennial crops, and individual experiments in most cases can be written up and disposed of in a short time. Except in the nursery, this does not happen in forestry, in which we are dealing with long-lived crops, and one result of our large programme of experimental work during the last thirty years is the accumulation of large numbers of field experiments which has resulted. Many of these have given their answer and have nothing more to tell; others, having answered the question which they were laid out to deal with, have, in the course of their growth, posed new questions. Old experiments which are still on our books are reviewed every year, and considerable numbers are formally closed and abandoned. This is a continuing process but, even so, the number of field experiments which remain is large, and their maintenance is a heavy task. Some of the old experiments are retained as demonstrations of methods which were once used and are now superseded, and some of our earliest experimental areas are now, in effect, museums in which the development of technique over a period can be demonstrated. In this way, they have a high educational value.

There have been relatively few changes in staff. It has been decided to form a soils section at Alice Holt to carry out routine determinations of the physical and chemical properties of soils, in conjunction with the other sections, and also to undertake a limited amount of primary soil research. As the new soils research officer, Dr. W. H. Hinson, formerly at the University College of North Wales, has been appointed.

A short time ago, the Commissioners decided to set up a small committee, under the chairmanship of Sir Henry Beresford-Peirse, Bt., to control and co-ordinate various aspects of work study, in which, among other things, the methods used in forest operations, and their efficiency, would be examined. This will include investigations of a type normally conducted by forest research organisations in other countries. Mr. J. W. L. Zehetmayr, who has been a research officer in Scotland for the last eight years, has been selected to take charge of the new organisation.

Visitors to the Research Station at Alice Holt increased in number from 252 last year to 424 during the year under review, a sharp rise which is a reflection of the growing interest in the activities of the Commission in research. These visitors included forest officers and others from the following countries:— Australia, Austria, Bolivia, Canada, Ceylon, Finland, France, Germany, Italy, India, Japan, Malaya, the Netherlands, New Zealand, Nigeria, Norway, Kenya, Pakistan, Sierra Leone, Sudan, South Africa, Sweden, Turkey, the United States of America, Uganda and Yugoslavia.

Alice Holt was visited by members of the British Association during their meeting in Oxford, and by the Royal Forestry Society of England and Wales, the Fabian Society Summer Schools, the Haslemere Natural History Society, and the Weybridge Natural History Society, as well as by parties of students from the Universities of Oxford, Aberdeen, and Edinburgh and from the

University College of North Wales. In the north, our Edinburgh branch arranged visits to various experimental areas for members of the Royal Scottish Forestry Society, members of the staff of the Nature Conservancy, students from the Universities of Aberdeen and Edinburgh and from the University College of North Wales, students from the East of Scotland College of Agriculture, for parties of district officers of the Forestry Commission and—a new departure—for parties of school children in Yorkshire.

Experimental areas in the north were also visited by forest officers from Australia, Austria, Belgian Congo, Denmark, India, Italy, Northern Ireland, Norway, Sweden and Switzerland.

The Director attended the meetings of the International Peat Symposium in Dublin in July, and the Annual Meeting of the Permanent Committee of the International Union of Forest Research Organisations which was held at Nancy in September, 1954. Mr. M. V. Edwards was a member of the British delegation to the Fourth World Forestry Congress held at Dehra Dun in December, 1954, and he took part in one of the tours organised in connection with the Congress. Mr. T. R. Peace attended the ninth session of the Permanent Committee of the International Poplar Commission which was held in Rome in April, 1954. Mr. Peace returned home by Switzerland where he paid visits to forests in the Lugano and Bellinzona districts, and also to the Institute of Special Botany and the Forest Research Station at Zürich, where he discussed with the Swiss authorities problems of common interest. In July, he took part in a meeting of Pathologists at Wageningen in Holland to discuss the fungus *Fomes annosus*, and he later attended another meeting of the International Poplar Commission in Paris, to consider the publication by the Poplar Commission of a book on poplars. Dr. F. C. Hummel attended a meeting of a working party of the International Union of Forest Research Organisations to discuss the standardising of mensurational symbols. This meeting also took place in Wageningen. Mr. E. G. Richards, Utilisation Development Officer, took part in a meeting of the Joint E.E.C./F.A.O. Working Party on Logging Techniques and the Training of Forest Workers, which was held in Geneva in June, 1954.

Various members of the research staff have taken part, as lecturers, in refresher courses for the staff of the Commission at Northerwood House, at the Forester Training Schools and at the Short Courses held for Woodmen at Chatsworth in Derbyshire. In addition, they gave lectures at Birmingham University, at the Royal Naval Technical College at Rosyth and at the Royal Forestry Society's course at Cirencester.

The Advisory Committee on Forest Research met twice during the year, once in London and once at Ross-on-Wye, when the members inspected experimental work in the Forest of Dean, in Dymock Woods, and at Tintern. The membership of the Committee has not changed during the year, but the retirement of Professor John Walton from the Forestry Commission, as a result of ill-health, has deprived the Committee of its Chairman. This we record with the greatest regret.

The sub-Committee on Nursery Nutrition held its Annual Meeting in October in the New Forest, when it reviewed the programme of nursery experiments.

A sub-Committee on Forest Soils was set up during the year to advise on research on forest soils. It is composed of Sir William G. Ogg (*Chairman*), Mr. G. V. Jacks, Professor Champion and Professor Steven.

Increased attention to utilisation has resulted in the testing of much more home-grown timber at the Forest Products Research Laboratory at Princes Risborough in Buckinghamshire. This work is proceeding on a plan agreed with the Commission, who provide the material for testing. This is selected in such a way as to make possible an evaluation of the quality of the wood which we are growing and, at the same time, a study of the effects of climate, site, and rate of growth, on the properties of timber. The help which has been so readily given by the Director of the Forest Products Research Laboratory and his staff is greatly appreciated. At the same time the Commission's Utilisation Development section has increased its activities. Among them may be noted the erection, at Santon Downham near Brandon in Suffolk, of an experimental timber building, to a design produced by the Timber Development Association, in which small-sized material cut from a variety of home-grown conifers is used. This building, which is being used as an office, is at present undergoing tests.

One notable event of the year was the acquisition of the well-known Forest Garden at Crarae near Inveraray in Argyll, which has been most generously presented to the Forestry Commission by Sir George I. Campbell, Bart., of Succoth. Part of the site was previously occupied by the characteristic birch and oak scrub of the district; part of it is covered with peat. A large number of plots, mainly of coniferous species, have been planted, and the species used cover a very wide range indeed, and include many trees which foresters rarely see in plantations. This area will undoubtedly prove of the greatest value in our research work and we are deeply indebted to Sir George for making it available for general study.

The Forestry Commission has continued to take an active part in the work of the International Union of Forest Research Organisations, in which the Director is a member of the Permanent Committee. The Union proposes to hold its twelfth Congress at Oxford in July, 1956, and arrangements are now being made for its reception in this country. The Congress will be followed by a number of tours, in the course of which visiting delegates will have the opportunity of studying our research and experimental work, and of examining the progress which has been made in forestry within recent years in Great Britain. This will be the first occasion on which the Union, as a whole, will have visited these shores.

Liaison has been maintained with the Nature Conservancy, by direct contacts, and through the medium of the informal joint committee which meets from time to time to discuss matters of common interest. The close contacts with the Imperial Forestry Institute, the Rothamsted Experimental Station, and the Macaulay Institute for Soil Research have continued and our thanks are due to the Directors of these Institutes for the help which they have given us.

During the year a number of publications have been issued by the Commission: among these are two Bulletins, one on *Experiments on Tree Planting on Peat* by Mr. J. W. L. Zehetmayr, in which a summary is given of a quarter of a century's work by the Research Branch; and the other, which was brought out in the Commission's series by arrangement with Professor Champion, on *Mull and Mor Formation in Relation to Forest Soils*, written by Dr. W. R. C. Handley of the Imperial Forestry Institute.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE

The Season

THE main features of the 1954-55 season were a spring, starting cold and wintry and becoming dry and sunny, with a spring drought, the April rainfall in the south being seventy per cent below the monthly average. It was, in fact, the driest April since 1938. This dry spell had some effect on seed germination but was not sufficiently long to cause serious losses in the nurseries. The period May to September was characterised by dull, cool and wet conditions. Temperatures were generally below average in almost every month, and in Scotland frost was experienced in July, and a severe early frost occurred in September causing damage in many nurseries. The rainfall was twenty to forty per cent above normal during the summer mouths. The remainder of the season was cold and showery, in some places the worst since 1947. Gales in December and January did damage in the south and west of the country, and the prolonged bad weather in early 1955 caused delays in the planting programme.

In Scotland, serious damage was done to many recently planted experiments by black game. The population of this bird appears to be on the increase everywhere. The vole plague that did some damage at Carron Valley Forest in Stirlingshire in 1954 appeared to subside, and little damage was done this season. During the snowy weather, damage by red deer was unusually serious.

PART I

This part of the Report deals with current work carried out by various sections of the Forestry Commission Research Branch.

Forest Tree Seed Investigations

Germination testing continued on an expanded scale, work being speeded up considerably by applying the moist pre-chilling technique described in last year's Report. In interpreting tetrazolium vital staining tests it is now found that occasionally misleading results may be obtained if attention is not paid to staining of the endosperm, since a seed with a fully live embryo may still not be viable if the endosperm is defective. Further tests on slow germinating species such as ash and lime confirmed that the endosperm here has an inhibiting effect, as quick germination of excised embryos was obtained. Seed storage tests were continued. Conifer seeds can be stored for four years with little drop in germinative capacity provided they are dried to the right moisture content and kept in sealed containers at 36°F. Various hardwood species have also received attention and results from investigations into the storage of acorns are given in Part III of this Report.

Nursery Investigations

PARTIAL STERILISATION OF SEEDBEDS

In the previous year, widespread user trials with formalin in Conservancy nurseries had given variable results, although in research nurseries consistently good effects had been repeatedly obtained. This year trials under more carefully controlled conditions were made in seventeen nurseries throughout the country, chloropicrin being tested in addition to formalin. In all nurseries except two, significant increases in height growth of seedlings were obtained, chloropicrin (at the rate of about thirty gallons per acre) giving as good or better responses than formalin. Responses were greater on ground that had been repeatedly cropped than on ground that had remained fallow. Chloropicrin did, however, cause a serious reduction in the numbers of seedlings in several cases, and this is attributed to sowing the seed before all traces of the sterilant had left the ground. It appears that, in most cases, at least a month should elapse between injecting chloropicrin at thirty gallons per acre and sowing the seed. Tests in six Scottish nurseries to determine the best rate and time of application of chloropicrin indicated that between thirty and forty gallons per acre (= thirty to forty ml. per square yard) gives satisfactory results, but that applications less than thirty-five days before sowing can cause serious reduction in seedling numbers. Further tests are necessary to establish the best rate of application and safe period before sowing for an average season.

SEEDBED COMPACTION

A repetition of the seedbed compaction experiments on three nurseries confirmed that rolling seedbeds before sowing, using a medium twelve-inch roller weighing one to four cwt., is a satisfactory procedure. A heavier roller (seven cwt.) gave slightly better results but not sufficiently so to compensate for the practical difficulties in handling it. No benefits were obtained from rolling after sowing and covering.

NITROGEN MANURING

In a series of nitrogen manuring experiments testing dates and methods of applying 'Nitrochalk' to Sitka spruce seedbeds, three years work on a wide variety of nursery sites, covering a range of climatic conditions, has confirmed that two top-dressings of 'Nitrochalk' in either August or July, or one in each month, give the greatest stimulus to height growth. 'Nitrochalk', if carefully applied, is safe to use and does not cause losses of plants in Sitka spruce beds, and there is no evidence that manuring with 'Nitrochalk' increases the chance of damage by early frost even when it is applied as late as the third week in August. Where frost damage has occurred, the control (unmanured) plots have been damaged as severely as the manured ones.

MAGNESIUM DEFICIENCY

In Inchnacardoch nursery, a magnesium deficiency in Sitka spruce, showing up as 'hard yellowing' of the foliage last year, was corrected by application of magnesian limestone at six cwt. per acre.

LONG TERM FERTILITY DEMONSTRATIONS

In the various long term fertility demonstration experiments, now in their fifth year, in which organic and inorganic fertiliser regimes, both separately and combined, are compared, the effect of purely organic manures in reducing seedling numbers is again confirmed.

As usual, the combination of organic and inorganic manures gave the biggest seedlings; but this year, in Newton and Teindland nurseries in Morayshire, the compost treated plots gave for the first time the larger plants than the plots manured with artificial fertilisers. (This was not the case at Bramshill nursery in Hampshire.)

IRRIGATION

Irrigation of seedbeds by overhead spray line at Kennington nursery, near Oxford, again showed improved growth and stocking in the most frequently irrigated treatments, in spite of a generally wet season, though there was a partial drought in April and early May. After five years, the pH has increased from 5.2 in the control plots to 6.0 to 6.2 in the irrigated plots, due apparently to traces of lime in the water; this may soon cause trouble. At Kinver nursery, where the season was particularly wet, there were no beneficial results from irrigation this year.

UNDERCUTTING

Undercutting experiments continued, and indicated that the best plants as regards root and shoot weight are obtained from thinly sown beds, undercut at a depth of two to four ins., either in August of the first year or March/April of the second year. Put out as 'one-undercut-ones' in the forest, the indications are that their performance is generally intermediate between that of one-plus-one transplants and that of second-year seedlings.

WEED CONTROL

Pre-emergence spraying experiments with mineral oils were extended to a number of conifer species, but poor germination precluded reliable assessments of the effects of the oils on the tree species, though it was clear that the heaviest application of vaporising oil (120 gallons per acre) reduced seedling numbers of Japanese larch. Weeding times were significantly reduced in all treatments. Trials with pre-emergent applications of pentachlorphenol (P.C.P.) and iso-propylphenylcarbamate (I.P.C.) gave reductions in seedling numbers, and in the case of P.C.P., only slight weed control. I.P.C. in general gave a significant degree of weed control.

Repeated post-emergence sprays with oils, notably various forms of white spirit, gave in general good weed control, with little or no damage to conifer seedlings, except in the heaviest doses on Japanese larch and Sitka spruce, in lighter doses on *Thuja* in one nursery, and to Norway spruce in two other nurseries. A cheaper form of weedkiller, Shell 'W' AG.2153, was found inferior to the ordinary Shell 'W'. More work is required before the safe applications for different conifer species can be determined, but much valuable data have been collected. 'User trials' of post-emergence applications of mineral oils on a large scale, on a wide range of sites, climates and species, gave in general good weed control, but vaporising oil, and the heavier applications of white spirit, caused some damage to Japanese larch, Douglas fir and Sitka spruce seedlings. Corsican pine was not affected. In transplant lines inter-row spraying with vaporising oil and with white spirit caused no damage to the crop, even at levels of application up to 120 gallons per acre, and at Bramshill such spraying gave very good weed control. (There were insufficient weeds at Kennington to assess the weed-killing effect.) Overall sprays caused significant reduction in growth, with scorching of foliage and death of leaders in Japanese larch, Douglas fir and Sitka spruce. Non-selective weed killers such as sodium trichloracetate (T.C.A.), chlorophenyldimethylurea (C.M.U.), sodium chlorate, and 2-, 4-D, in a range of strengths, were tested for controlling weeds in fallow areas last year. Residual effects this year were negligible in all cases, except for C.M.U.; conifer crops, with the notable exception of Douglas fir, suffered badly on ground treated with this chemical in the previous season.

SEEDBED COVERS FOR ABIES GRANDIS

Preliminary indications are that this species likes deep ($\frac{3}{4}$ inch) covering, and is equally happy with a soil or grit cover.

Problems of Afforestation

PILOT PLOTS

Turning to afforestation problems, the pilot plots planted on difficult peat areas in the north are mostly still showing good growth—some of them are eight years old now—but it is evident that exposure to wind is a more serious factor affecting establishment than soil conditions. A scheme for evaluating the exposure factor by the rate of tattering of un-hemmed linen flags of a standard design has been put into effect over a wide range of sites, to determine what degree of exposure to wind can be considered as limiting, beyond which further species trials on the present lines would be pointless.

On the Lizard peninsula of Cornwall, on soils over serpentine rock, a trial of some nineteen species has been laid down, including mixtures with the hardiest species for protection from sea winds. Direct sowings, which failed in the previous year, are being experimentally protected by a spray of bituminous emulsion after sowing. Bituminous emulsion sprays are also being tried for fixing sand dunes at Newborough Warren, Anglesey, following successful Russian practice.

Studies and trial plantings are being made in several areas of checked or failed plantations notably in parts of Tarenig and Hafren Forests in Central Wales, Wilsey Down in Cornwall, and Wareham in Dorset.

EXPERIMENTAL PLOUGHING

Preliminary trials have been made with an Australian 'Majestic' multiple disc plough on heathland in Yorkshire, to try and get an economic and satisfactory method of ground preparation for planting that has not got the disadvantages of the high ridge and deep furrow at present produced in standard ploughing practice. Trials are also being made with triple superphosphate in place of ground mineral phosphate, for manuring at the time of planting; since, if successful, it will reduce by two-thirds the weight of manure distributed.

MIXTURES

A long-term mixture experiment has been laid down at Gisburn, Lancashire. with ten treatments including pure and mixed crops of both conifer and broadleaved trees. Soil changes and the turn-over of nutrients will be intensively studied by the Nature Conservancy in these plots. A two-species mixture of Sitka spruce and *Tsuga heterophylla*, with pure control plots of each species, has been laid down in five localities to study the yield and quality of the produce and the effects on the site.

PROVENANCE

Notes are given on the extension of provenance work with lodgepole pine, Sitka spruce and Douglas fir. The appearance of the disease *Rhabdocline pseudotsugae* on some coastal origins of Douglas fir, hitherto believed to be immune, will necessitate a re-assessment of the position as regards this disease.

DERELICT WOODLANDS

In derelict woodland investigations, special attention has been given to exploring the most economic methods of converting rhododendron ground into useful forest land. Cutting strips through it and planting with heavy shade-casting conifers proved to be initially much cheaper than clear cutting, but there is no further saving in initial costs if the width of the cleared strips is less than about half the height of the rhododendron. The other main investigation has been in methods of treating hardwood scrub on heavy clays, where comparisons are being made of the cost of clearing by heavy machinery which either (1) up-roots the scrub, or (2) cuts it off at ground level. Drainage effects on these heavy clays are also being studied. Trials are also being carried out on the chemical control of woody weeds—basal bark sprays with the butyl ester of 2, 4, 5-T in oils giving promising results on oak scrub. The only chemical that so far shows any promise for the control of rhododendron is ammonium sulphamate.

CHEMICAL REPELLENTS

Work continues on animal repellents for the protection of planted trees against rodents, and of seeds against birds and mice.

Ecology

The ecologist has commenced studies on the effect of drains in heavy clay, on the factors affecting the natural regeneration of beech, and on the ecology of Corsican pine. A survey of site factors in checked plantations in mid-Wales has also been made.

Poplars

In poplar work, eleven major and twelve minor trials have been planted in Great Britain, to test the growth and disease resistance of a large number of poplar clones. The number of clones now held numbers over 300, although many of these are only of botanical interest.

Work in the populetum was continued, and 125 clones have now been planted. Eight silvicultural experiments were planted during the winter, and assessments on other experiments were carried out at the end of the growing season. Many of the older projects have been informative, and results will be published at an early date.

Over 32,000 cuttings of standard varieties and 1,200 cuttings of other varieties have been distributed to outside nurseries and research stations during the year.

Genetics

SEED SOURCES

In the Genetics section, the survey of seed sources in Scotland, begun in 1951, was practically completed during 1954. A total of 657 woodlands and plantations has been classified, and a Register of Seed Sources has been compiled for each Conservancy. Scots pine seed sources account for over half, and larch, Douglas fir and Norway spruce seed sources for one quarter, of the total area of just over 4,400 acres of 'plus' and normal seed sources.

The selection of plus trees continued, the total marked and recorded now being 1,552. 255 of these trees were propagated by grafting during the spring of 1955. 10,360 grafts were attempted, and fifty-nine per cent of these were successful. Good results were obtained in the propagation of the larches by summerwood cuttings, by the use of a new propagation frame incorporating sub-irrigation and electrical soil warming.

SEED ORCHARDS

Six seed orchards, totalling eighteen acres, have now been established. Work has begun on three more seed orchards, totalling thirty-seven acres, and three new seed orchard sites were selected in Southern England. The species concerned are Scots pine, the larches, Douglas fir and beech, in that order.

The report by species describes the flowering of some four-year-old grafts of beech. One clone in particular flowered quite well, four out of eight grafts producing from two to nine female flowers. The amount of flowering appeared to be related to the amount of woody growth of the previous season. Moderate growth was correlated with good flowering, but very vigorous or very poor growth were both correlated with poor flowering or none.

HYBRIDISATION

Small scale intra- and inter-specific hybridisation of the larches was continued at Alice Holt. Eight fine stands of Scots pine were found in south Scotland, and plus trees were selected and propagated by grafting, so that seed orchards can be formed for the production of seed of each origin.

Studies of Growth and Yield

The establishment of new sample plots was mainly confined to spacing experiments, to conifers less commonly planted such as *Tsuga* and *Thuja*, and to hardwoods. A revised code of procedure for sample plot work, incorporating all the modifications in sample plot practice since 1931, has been drafted.

The Statistical Section, in addition to advisory and computational work, has made special studies of experimental designs to suit forestry problems. The draft of a publication on the 'Application of Statistical Methods to Forest Research' is nearing completion. Investigations into certain aspects of forest management have been commenced.

Census work has continued according to programme, and the counties of Ross and Cromarty, Flint and Berkshire have been completed. A somewhat simplified procedure has been introduced to speed up the work.

Pathology

Certain fungal diseases were unusually active this year. Heavy attacks by *Lophodermium pinastri* on pine started to appear at the end of the period under review, while *Keithia thujina* was unusually virulent on *Thuja* in nurseries. *Rhabdocline pseudotsugae* was noted for the first time on Douglas fir of coastal origin: and *Meria laricis*, the leaf cast of larch, was recorded for the first time in this country on Japanese and Hybrid larch.

Group-dying of Sitka spruce remains unexplained, though a similarity between the groups of trees affected, and those where death is caused by diffused lightning strikes, is being followed up. But a physiological explanation, based on disturbance of the water-intake/evaporation balance, has been put forward to account for the top-dying of Norway spruce, which has been recorded in many parts of the country.

Test areas, where strains of tree can be tried for resistance and susceptibility, have been set up for two rust fungi, *Cronartium ribicola* on five-needled pines and *Ribes* (currants), and *Melampsora pinitorqua* on two-needled pines and aspen poplars. Varietal testing of poplars by inoculation on a large scale with bacterial canker continues, and considerable progress has been made in raising Dutch stocks of elms supposedly resistant to 'Elm Disease', for testing under conditions of heavy natural infection.

Some progress has been made in the testing of sprays against *Botrytis cinerea* attacking conifer seedlings, but another severe attack on spruce seedlings, following autumn frost, underlines the necessity for further work on this difficult-to-control disease. Failure of three more isolated nurseries to remain free from infection by *Keithia thujina* throws doubt on the feasibility of combating this disease by the policy of growing *Thuja* in isolation. Plans are being made for further spraying experiments against this fungus.

Preparatory work is under way for large scale experiments on *Fomes annosus* particularly in relation to second rotation crops. Mainly because so many of the trees have remained attached to the ground and alive, decay has not proved at all serious in those trees still lying after the Scottish windblow of 1953.

Entomology

Much of the Entomological Section's work was devoted to studies on the Pine Looper Moth and to the control campaign against this pest at Cannock Chase (Staffordshire) and Culbin (Morayshire) forests. At Culbin, 1 lb. of DDT in three gallons of spray liquid was applied per acre from fixed-wing aircraft, and the treatments have proved effective in reducing the *Bupalus piniarius* population in these areas to an endemic level. The pupal survey carried out in winter 1953-54 has recorded a major fall in population densities in forests in all parts of the country. In only one area—Sherwood 4 (Clipstone)—has a disturbingly high count been maintained. Here, the highest compartment mean is 12 pupae/sq. yd. as compared with a figure of 9 pupae/sq. yd. in 1953-54.

Development of Pine Beetle (*Myelophilus*) in the gale-damaged areas of north-east Scotland has again been surveyed; breeding in 1954 was extensive, as the blown pine died off. The impact of this increased population on standing crops will become obvious in the 1955 growing season, and is expected to be serious. The Pine Weevil, *Hylobius abietis*, continues to breed in the devastated areas as clearance progresses, but rapid exhaustion of breeding sites, coupled with a rather patchy distribution of infestation, indicates that this epidemic will be less severe than anticipated.

The annual larch sawfly survey had to be discontinued because of pressure of other work, but the laboratory studies of the sawflies associated with larch, spruce and pine were continued. One further new species on larch was identified.

Further experiments on the protection of newly planted conifer crops from *Hylobius abietis* attack by means of insecticidal dust treatments gave encouraging results, and work on this subject is being developed to include spraying and dipping as well as dusting.

Grey Squirrels

A brief note is included on the work that is being done in co-operation with the Ministry of Agriculture, Fisheries and Food on the grey squirrel. This work covers both population and movement studies, as well as methods of control of the pests.

Machinery Research

Work continues to be divided between the design and development of machinery for specific forestry operations and trials of those new machines coming on to the agricultural machinery market which may be applicable to forestry. An endurance trial of the special bog tractor built from Fordson County components has shown that this machine possesses a satisfactory standard of reliability.

Trials of one-man power saws have revealed a suitable saw weighing less than 25 lb. Nursery operations are being gradually mechanised. New devices for the extraction of thinnings have been tested and approved. A large-scale trial is now in progress covering most of the known machines suitable for the clearance of derelict woodland. The problem of cleaning drains in young plantations by machinery remains unsolved, but work is proceeding.

Utilisation Development

The Utilisation Development Section, under the guidance of the Advisory Committee on the Utilisation of Home Grown Timber, continued to devote most of its attention to the development of markets for the types of woodland produce which are difficult to utilise. A significant advance was made in this field when two paper-making concerns expressed an interest in the possibility of pulping hardwoods. Investigations to see whether this would be practicable have been pursued. If hardwood pulping mills were established, it would result in a new market for hardwood thinnings, scrub and overgrown coppice of certain species.

In the field of conifer thinning, the prototype of the 'Thinnings House' referred to in last year's report was erected. Other projects included a survey of the chipboard and wood wool slab industries, and an enquiry into the use of home-grown timber in boxes, pallets, and other forms of materials handling.

More analyses of home grown barks were obtained, and a study of the variation of the tannin content of Sitka spruce bark grown under different conditions was commenced.

PART II

IN this part of the report, accounts are given by outside workers on research, usually of a more fundamental nature than that carried out by the Forestry Commission Research Branch, which is being conducted mainly under grants from the Forestry Fund.

Nutrition Problems in Forest Nurseries

Miss Benzian of Rothamsted Experimental Station, Harpenden, reports briefly upon work carried out in 1954 on nutrition problems in forest nurseries. Consistent responses to manuring with phosphorus, applied as superphosphate, on a wide range of nursery sites, suggested that still heavier applications might be tried with advantage. Responses to potash were smaller and more variable. Partial sterilisation of the soil by both chloropicrin and formalin was tried at different seasons of the year, June, November, December, and February; these gave almost equally good results irrespective of the season, with the single exception of formalin in June which was not so good. A new fumigant, 'CBP.55' (chlorobromopropene) has been tried and has given results closely comparable to those obtained from chloropicrin.

Soil Profile Development

Dr. T. W. Wright at the Macaulay Institute, Aberdeen, studying the nutrition of Corsican pine on the Culbin Sands, has continued the periodic analysis of leaf material collected from the Culbin thinning plots. It appears from the preliminary results that heavy thinning, by delaying the drying out of the sand, improves the nutrient up-take of the trees in early summer.

No obvious response to phosphate manuring was observed in the young Corsican pine treated in April, 1954, but height growth was found to be correlated with foliage nitrogen content (cf. Leyton, *Rep. For. Res.* 1953, p. 105). The experiment is being continued for another year.

Investigations have been started into the physical and chemical changes occurring as a result of the afforestation of deep peat, and into soil changes taking place in two of the older sets of replicated thinning plots.

Tree Nutrition

Dr. L. Leyton at the Imperial Forestry Institute, Oxford, has continued his studies on the nutrition of trees. The pronounced growth response from mulching Lawsons cypress on a *Calluna* heath in east Yorkshire is found to be associated with an increase in the nitrogen and phosphorus contents of the foliage. Growth variation of Japanese larch on these heaths was found to be directly correlated with the concentration of potassium and nitrogen in the foliage. In Scots pine, similar correlations between height growth and potassium and nitrogen content of the needles, were found on a southern sandy heath at Bramshill Forest, Hampshire. The effect of controlling light, temperature and oxygen tension on the growth of tree roots of a wide range of species, is being investigated under laboratory conditions.

Fungal Damage to Seedlings

D. M. Griffin, working at the Botany School, Cambridge, has come to the conclusion that the amount of damage done to the root tips of seedlings of Sitka spruce in unsterilised soils in certain nurseries is not sufficient to account for the very large responses in seedling growth caused by partial sterilisation. Work is continuing, to try and elucidate the factors at work.

Soil Mycology

Dr. I. Levisohn continued her work at Bedford College, London, on soil mycology. She has demonstrated the 'rhizosphere effect' on Norway spruce, birch and *Robinia* seedlings through inoculating the soil with *Boletus scaber* cultures. In no case was any mycorrhizal association found though notable stimulation of height growth resulted. The case of *Robinia* is interesting as an example of stimulus by an ectotrophic mycorrhizal fungus of a species that normally has endotrophic mycorrhizas. Leaching water from soils infected with mycorrhizal forming fungi caused stimulation in short-root development in larch, Sitka spruce and Norway spruce, again without the formation of any mycorrhiza.

For experimental purposes *Boletus scaber* has proved to be a very convenient and interesting fungus which will grow vigorously on a variety of media. It appears to be a transitional type of soil fungus on the boundary between mycorrhiza formers and litter decomposers, and seems to exert a delaying effect on the development of other mycorrhizal mycelia. Further studies are being made on this phenomenon of the interaction between various species of mycorrhiza-forming fungi.

Larch Canker

At Southampton University, Dr. J. G. Manners has continued his work on European larch canker. Anatomical studies of cankers produced by inoculation with *Trichoscyphella willkommii* have confirmed that anatomical abnormalities of cankers can be produced by inoculation in the absence of frost. Freezing experiments have, however, shown that similar cankers can be produced by frost and further experiments have been started to determine the relative importance of the two factors and of other subsidiary factors in initiating and perpetuating cankers.

The taxonomy of British and related Trichoscyphelloideæ has been studied further, and a key for the separation of the species prepared.

Morphological Variations of Conifers

Dr. E. V. Laing and Dr. A. Carlisle at Aberdeen University have continued the intensive study of lodgepole pine with a view to establishing and defining the differences in trees of different origins. Material for this study is being obtained from Forestry Commission provenance plots.

Work on Douglas fir has also been continued while the study of morphological differences in Scots pine has been completed. A study of the birch in Scotland has been initiated and some preliminary information obtained.

Bioclimatic Studies on Pine Looper Moth

The microclimate affecting eggs and larvae of the Pine Looper Moth, *Bupalus piniarius*, has been investigated by Dr. N. W. Hussey of Edinburgh University to provide a background for laboratory experimentation and to simplify more accurate interpretation of standard meteorological records. Intensive work on the effect of temperature and air moisture on larval feeding was carried out in order to facilitate interpretation of continuous coprometer records in the coming year.

The collection and despatch to New Zealand of *Amblymerus apicalis*, the principal parasite of the Douglas Fir Seed Fly, *Megastigmus spermotrophus*, is reported. Some 1,800 parasites were flown out and released at three centres.

Soil Faunal Investigations

Dr. P. W. Murphy of Rothamsted Experimental Station, describes an improved apparatus for the extraction of meio- and meso-fauna from the soil, and summarises the results of tests on different methods of treating the soil samples for extraction. In general, it is found that the largest numbers of these animals are obtained if the litter and the raw humus are handled in the extraction apparatus separately from the soil, and if the samples are in an undisturbed condition.

Dr. Murphy has spent a year in Austria with Professor Kühnelt at the Zoological Institute of the University of Vienna, where he has been studying the food habits and biology of individual species of soil organisms.

Shelterbelts

J. M. Caborn of the Forestry Department, Edinburgh University, has continued investigations of the effects which shelterbelts exert on the microclimate of adjoining areas, with the object of determining suitable belt structures. Studies have concentrated mainly on wind conditions in the vicinity of various shelterbelts, but, to support these, a technique and suitable equipment have been devised for the comparative study of evaporation rate. These have replaced instantaneous measurements of atmospheric humidity and temperature factors.

In order to elucidate certain fundamental problems of shelterbelt design, of particular importance in connection with shelterbelt technique on upland areas, wind-tunnel studies have been made of the relationship of belt width and cross-sectional profile to the leeward sheltered area. A simple method is being formulated for the assessment of the protective efficiency of existing shelterbelts, with a view to increasing their effectiveness by appropriate cultural measures.

PART III

IN this section, the results of certain investigations carried out by the Forestry Commission Research Branch are reported in the form of short articles. The main points of interest are summarised below.

Acorn Storage

In a study of the best methods of storing acorns, G. D. Holmes and G. Buszewicz found that out of 13 methods of storage begun in 1950, all acrons were dead in 12 months except in three methods, in which a constant temperature of 36°F. had been maintained throughout the experiment. The moisture content of the acorns was critical, and had to be kept between 40 and 45 per cent, and it was also found that sealed containers, in which the carbon dioxide concentration became high, caused early death of the seeds. The best method was to use sound seed having a moisture content of 40 to 45 per cent on fresh weight, and stratify it in dry peat or sand in a closed but unsealed container at a constant temperature of 36°F. Under these conditions a drop of only 20 per cent in the germination capacity occurred after 36 months, and 52 per cent were still alive after 42 months.

'Shell D.D'

R. Faulkner presents a paper on the use of the proprietary fumigant 'Shell D.D' (dichloropropane-dichloropropylene) for the partial sterilisation of nursery soils. When compared with formalin, 'Shell D.D' was found to be a less effective steriliser; but it was easier to apply.

Disbudding Conifers

Interim results in a series of intensive experiments in disbudding as an alternative to saw pruning are reported by J. W. L. Zehetmayr and J. Farquhar. The method has interesting possibilities for Scots and Corsican pines and possibly even for Norway and Sitka spruces, and is being compared with controls, in intensive experiments. After six years the reduction in height growth through disbudding is not severe though there is a considerable loss in girth increment on the disbudded stem. Fast growing Douglas fir has proved unsuitable for disbudding owing to the resultant dieback of the leaders.

Seasoning Before Extraction

In 1952, experiments were begun to see what happened to trees left to season at stump after felling, and to determine whether extraction of these poles was markedly easier than the extraction of fresh-felled ones. The results of the extraction trials are discussed by C. D. Begley, and the effect of seasoning on peeling is also considered. Although the time taken to extract the seasoned poles to ride-side was shown to be less than the time for extraction of unseasoned poles, the time expended in stacking, on brash, those poles that were to be seasoned before removal to the ride, equalled any saving in time on extraction of seasoned poles. The rate of peeling, under the particular conditions of this experiment, was unaffected by seasoning. The studies on degrade, natural loss of bark, and insect and fungal damage, are not yet sufficiently advanced to be discussed.

Moisture Content of Fresh-Felled Hardwoods

In the course of investigations into the suitability of home-grown hardwoods for pulping, it was necessary to convert yields of green timber into their oven-dry weight, and accordingly data were required on the moisture content of fresh-felled hardwoods. Certain information was already to hand as a result of investigations into moisture content for other purposes. This was supplemented by sampling timber from two forests in south-west England which also provided figures on the moisture content of stem and branchwood, and that of wood from trees of different ages. The work is described here by C. D. Begley, with a statistical analysis by J. N. R. Jeffers. It reveals the extent of tree to tree variation for different species and shows it to be a matter of perhaps greater interest than the variation from species to species or variation within the tree. These other factors are also discussed statistically.

Poisoning Trees to Facilitate Bark Removal

The use of chemicals to facilitate the removal of bark in conifers is the subject of a paper by G. D. Holmes. These trials comprise a series of preliminary tests in which a range of tree poisoning techniques were compared for Corsican pine, Japanese larch and Douglas fir, using sodium arsenite and other toxic chemicals. With the exception of Douglas fir, sodium arsenite in 40 per cent (As_2O_3) solution applied to band girdles in late spring was found to facilitate bark peeling in autumn and spring following treatment. The weight of the peeled trees was, at the same time, considerably reduced. Ammonium sulphamate, sodium chlorate, 'sodium 2, 4-D' and '2, 4, 5-T' were much less effective than sodium arsenite. Band girdles three to six inches wide painted with the solution were the most effective. Douglas fir proved very difficult to kill and showed loosening of the bark only after application of impractically large quantities of sodium arsenite. No serious attacks by fungi or insects were observed in any of the species under test. The technique holds promise, not only in reducing the cost of peeling and in handling the timber after peeling, but also in extending the time of peeling to any part of the year, though the chemical must be applied in the spring when the sap is rising. With normal care, the toxic hazards of using sodium arsenite are very slight. Further trials on a larger scale are being started and the work is being extended to other species including hardwoods.

Barr and Stroud Dendrometer

The measurement of standing sample trees in Sample Plot work has always been a problem. J. N. R. Jeffers describes a dendrometer based on a range finder principle which has been designed to measure from the ground diameters at various points up a tree, together with the height of these points above the base. Tests of the accuracy of the instrument are reported and its method of use in the field is given. This instrument is now in regular use in the Mensuration Section, and is proving highly satisfactory.

Part I. Reports on Work carried out by Forestry Commission Staff

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES and G. BUSZEWICZ

(232.31)*

IN the period under review, 530 samples of home-collected and imported seed were submitted for analysis to the Seed Testing Laboratory at Alice Holt. The total number of purity and germination tests carried out during the year was: Purity tests, 530; Germination tests, 1,000; Chemical Viability tests, 160. In addition 137 samples were examined for seed moisture content.

As in previous years, the bulk of the programme of routine seed analyses was carried out in the period October to May. Germination tests were considerably speeded by extensive use of the moist prechilling technique described in *Rep. For. Res.* 1954, p. 84. The tetrazolium test proved invaluable as an emergency method of assessing seed viability for late-arriving samples, and also for any samples on which a report was required within a few days.

Germination Test Methods

Biochemical Tests (232.318)

The examination of triphenyl tetrazolium bromide as a chemical indicator of seed viability for rapid estimation of seed quality was continued into its fifth year in 1953. In 1954, the field tests concerned with this investigation were discontinued to allow time for detailed analysis of the large amount of data then available from five years work. The scope of the trials carried out from 1949 to 1953 was considerable, and has yielded data on results of chemical viability tests, normal germinator tests, and field sowings in over fourteen nursery centres for seeds of nine common conifer species.

The tetrazolium test method has proved generally satisfactory, using a technique in which the estimate of seed viability is based on the extent of the staining reaction in the seed embryo. However, several continental workers maintain that the staining reaction of the seed endosperm should also be taken into account, or misleading results may be obtained. Recent experience at Alice Holt indicates that endosperm staining may be important, particularly for seed lots which have been damaged by heat or mechanical injury. A series of tests carried out on such seeds showed considerable discrepancies between the results of tetrazolium and standard germination tests, which could not be accounted for by normal sampling errors. In these cases the tetrazolium test based on embryo staining alone gave an overestimate of the real germination results. Examination of seeds deliberately damaged mechanically or by heat showed a considerable number of seeds with fully stained embryos, but with unstained or only partially stained endosperm tissues. A more detailed series of tests is now under way to examine the significance of the staining reaction of the endosperm in the assessment of seed viability.

In 1953, the tetrazolium test was approved by the International Seed Testing Association for application to certain tree species which germinate too slowly to

*This and similar numbers refer to the Oxford System of Decimal Classification for Forestry.

be tested conveniently by normal methods. These species include *Fraxinus*, *Prunus*, *Carpinus*, *Pyrus* and *Tilia*. During 1954 some time was spent in working out a detailed procedure of test for these species for presentation at the I.S.T.A. Training Course for Senior Seed Analysts held at Cambridge in June, 1954.

Excised Embryo Methods

Some attention has been paid to the possibility of utilising the excised embryo technique for germination tests on seeds of slow germinating or dormant species. Results have been encouraging and a satisfactory technique has been developed for *Fraxinus*. A number of tests with partially and completely excised embryos of *Fraxinus* and *Tilia* proved most interesting, and confirmed the view that the normal inhibited germination of these species is associated with the seed endosperm. No germination was obtained while any endosperm remained in contact with the embryo. Embryos completely denuded of endosperm tissue germinated rapidly, and tests could be completed within three weeks, compared with several months for unstratified whole seeds. These trials are being continued in order to obtain a clearer understanding of the nature and cause of the inhibited germination of these species.

Examination of Seed Quality in Cone Samples taken prior to Bulk Collection

Reports were issued on thirty cone samples received from Conservancies during the year. There is a need for a simple and reliable technique to enable field foresters to assess the likely yield of sound seeds from cones before large-scale collections are made. Work is in progress to test the accuracy of a method based on examination of the cut surface of sample cones as a means of obtaining a rapid estimate of the yield of sound seed. A special tool has been developed for obtaining accurate radial longitudinal sections through cones, and tests are being made on Scots and Corsican pine cones collected from a wide range of origins throughout the country.

Seed Storage and Seed Longevity

Storage of Hardwood Seeds (232.315)

Acorns. A report on trials with various methods for prolonged storage of acorns is given on p. 88 of this report.

Birch. Birch has not normally given difficulty in storage, but the results of a series of tests started with *B. pendula* in 1950 are of interest and worth quoting (Table 1).

COMPARISON OF STORAGE METHODS FOR BIRCH SEED

Table 1 Germinative Capacity

Storage Temperature and Method	Years of Storage				
	0	1	2	3	4
Unheated. Dry sealed	27	21	20	16	0
Unheated room. Moist peat ...	27	0	—	—	—
36°F. Dry, sealed	27	20	22	24	19
36°F. Moist peat	27	0	—	—	—
25°F. Dry, sealed	27	19	20	21	18
25°F. Moist peat	27	21	17	5	0

The seed can be kept in good condition for at least four years if stored dry in a sealed container at near freezing or below freezing temperatures. Moist storage was fatal except at the sub-freezing temperature of 25°F.

Storage of Conifer Seeds

The storage trial started in 1950 with seeds of larch, pine, and spruce species was continued into its fifth year. The results to date are presented below in Table 2.

GERMINATIVE CAPACITY OF PINE, SPRUCE, AND LARCH SEED DURING FOUR YEARS OF STORAGE

Table 2

Germinative Capacity

Species	Storage Method	Seed Moisture Content After 4 Years (% of wet wt.)	Years of Storage				
			0	1	2	3	4
Scots pine ...	Sack, unheated room ...	8.9	94	79	33	—	—
	Dry, sealed; unheated room	5.4	94	94	89	—	—
	Dry, sealed, 36°F. ...	5.7	94	97	96	—	—
Corsican pine	Sack, unheated room ...	10.4	71	35	19	5	1
	Dry, sealed; unheated room	9.3	71	63	58	47	17
	Dry, sealed, 36°F. ...	7.8	71	66	63	59	63
Sitka spruce ...	Sack, unheated room ...	10.2	72	23	2	0	—
	Dry, sealed; unheated room	9.7	72	76	69	65	45
	Dry, sealed, 36°F. ...	8.9	72	75	78	70	78
Norway spruce	Sack, unheated room ...	10.2	82	74	54	20	3
	Dry, sealed; unheated room	9.3	82	83	84	79	63
	Dry, sealed, 36°F. ...	9.2	82	84	91	85	73
European larch	Sack, unheated room ...	13.0	18	1	0	—	—
	Dry, sealed; unheated room	11.6	18	14	13	12	1
	Dry, sealed, 36°F. ...	11.4	18	15	13	16	10
Japanese larch	Sack, unheated room ...	12.9	32	7	2	0	—
	Dry, sealed; unheated room	12.0	32	25	6	7	0
	Dry, sealed, 36°F. ...	12.6	32	27	25	16	10

Storage sealed at a constant temperature of 36°F. gave the best results for all species. Unsealed storage in a sack in an unheated room resulted in a rapid decline in seed quality for all species. In most cases there was also an increase in seed moisture content. Storage in a sealed container in an unheated room was superior to storage in sacks, but the higher and fluctuating temperature resulted in a more rapid decline of seed quality than storage sealed at a constant temperature of 36°F. Both larch specimens showed quite rapid decline in quality with all three methods of storage, and it is thought that this is due to the high initial moisture content of the seed of these species. Recent experience indicates that drying the seeds to less than ten per cent moisture content results in a better retention of viability in storage. Sub-freezing temperatures have been used with success for storage of some conifers, but taken over the four-year period of storage described above there seems to be no advantage over a near freezing temperature of 36°F.

Determinations of Seed Moisture Content

Seed moisture content is of considerable importance in storage and in the past there has been some difficulty in standardising the technique of seed moisture content determination. With oven-drying methods, if the drying is prolonged or carried out at too high a temperature, there may be misleading results owing to the quantities of volatile constituents other than water contained in tree seeds.

Investigations are under way with several oven-drying methods, in order to arrive at a safe standard method for each type of seed. Preliminary tests with a grain moisture hygrometer for rapid estimation of seed moisture content are encouraging, and indicate that such an instrument may be of value for approximate determinations of moisture in stored seed providing the moisture content is below twenty per cent.

Seed Pretreatment

An investigation of pretreatment of the seed of wild cherry, *Prunus avium*, was completed to examine the effects of the duration of dry cold storage and moist stratification on the rate of seed germination. Field sowings showed rapid germination in spring from autumn sown seeds and from seeds sown in spring after two months stratification in moist peat. Longer periods of stratification even at a constant temperature of 36°F. gave poor results owing to pre-germination of seeds in storage. Seeds stored dry and sown in spring gave poor and sporadic germination.

Seed Sampling

A preliminary investigation of the errors occurring in sampling seeds from storage containers for purity and germination tests was started during the year.

Seed-borne Fungi

A report on the work of Dr. S. Batko at Alice Holt on the incidence of fungal infestations on germinating seeds was included in *Rep. For. Res.* 1954. This work has continued and the following additional species have been isolated: *Echinobotryum atrum*, *Fusarium avenaceum*, *F. oxysporum aurantiacum*, *F. bulbigenum blasticola*, *Graphium* sp., *Gliocladium roseum*. In all, 34 species have been isolated and tests of the pathogenicity of these fungi will shortly be started.

Other Activities

Collaboration with the Forest Seed Committee and the Biochemical Viability Test Committee of the International Seed-Testing Association was continued, and a number of reference samples were analysed. In June, 1954, the authors participated in a course for Senior Seed Analysts organised by the Organisation for European Economic Co-operation, at Cambridge.

NURSERY INVESTIGATIONS

By R. FAULKNER and J. R. ALDHOUS

Partial Sterilisation of the Soil

Formalin and Chloropicrin User Trials (232.322.2)

A series of experiments, in continuation of the trials carried out in 1952 and 1953, was carried out in thirteen heathland and agricultural soil type nurseries in England and Wales in 1954. These experiments compared the growth of seedlings of Norway spruce and Sitka spruce on beds treated with formalin and with chloropicrin.

As in previous years, formalin as a dilution of commercial thirty-eight per cent formalin in water, was applied, as a drench, at the rate of 5 gal. formalin in

100 to 200 gal. water per 100 square yards (0.05 gal. of formalin in 1-2 gal. water per square yard).

Chloropicrin was applied at the rate of 0.62 gal. per 100 sq. yds. (32 ml. per sq. yd.) by injection gun (*see* Photo 4) in shots of two ml. at sixteen points per sq. yd.

Full fertiliser applications were given before treatment.

Production of seedlings was unaffected by formalin treatment in nine nurseries. In three, formalin significantly or appreciably reduced seedling numbers, and in one nursery, Pembrey, it significantly increased seedling numbers.

Chloropicrin had no effect on seedling numbers in eight nurseries, in four nurseries it significantly reduced seedling numbers; while, at Pembrey, it significantly increased numbers of seedlings.

The drop in seedling numbers in sterilisation treatments is attributed to sowing before the last traces of sterilant had left the soil.

At eleven nurseries both formalin and chloropicrin significantly increased height growth of seedlings. There was no consistent relationship in the response in height growth, as between sterilants. In some cases formalin produced a better response than did chloropicrin, in others chloropicrin produced the better response, while in yet others there was little to choose between them.

The results of this and previous experiments are not yet clear cut. The indications are: (i) that sterilisation produces more favourable effects on ground cropped for the second year, than it does on ground sterilised following fallowing, (ii) that responses are smaller on heavy soils, and on highly alkaline soils.

A separate series of large-scale sterilisation trials of chloropicrin and formalin was conducted in Scotland. These compared the effects of chloropicrin injected at a depth of four inches at 0.62 gal. per 100 sq. yds. and formalin at 5 gal. per 100 sq. yds., suitably diluted with water and applied as a drench. Indicator species were: lodgepole pine at Inchnacardoch, Inverness-shire and at Fleet, Kirkcudbrightshire; Japanese larch at Newton, Morayshire; and Norway spruce at Benmore, Argyll. At all these nurseries both formalin and chloropicrin increased the mean height of seedlings and (with the exception of Fleet) chloropicrin produced much taller seedlings than formalin. At Benmore and Newton nurseries, seedling numbers were reduced by the application of chloropicrin. This was probably due to an insufficient lapse of time between sterilising and sowing.

Weeding times were significantly reduced by formalin at Newton. Treatments at other nurseries did not affect weeding times to any great extent.

Time and Rate of Application of Chloropicrin

At Inchnacardoch; Newton; Tulliallan, Fife; Benmore; Fleet; and Wykeham, Yorkshire, an experiment was carried out to determine the most effective concentration of chloropicrin within the range of 0.21 to 1.43 gallons per 100 square yards (10 to 70 gallons per acre). The chloropicrin was injected at four inches depth, either ten, twenty or thirty days before sowing. Formalin applied fourteen days before sowing, at ten gallons per 100 square yards, suitably diluted with water and applied as a drench, was used for comparison. Sitka spruce was used as the indicator species.

At the majority of nurseries chloropicrin at 0.84 to 1.43 gallons per 100 square yards (40 to 70 gallons per acre), when compared with formalin, produced a very noticeable depression on the rate of early seedling germination. This depression was most pronounced in those treatments wherein it was applied ten or twenty days before sowing. From the germination data and results at the end of the growing season, it was quite obvious that a lapse of more than thirty days is required between the time of applying chloropicrin and the time of sowing, since the 0.84 to 1.43 gallons per 100 square yards applications produced taller, but proportionately fewer, seedlings. A rate of 0.53 gallons of chloropicrin per 100 square yards (twenty-five gallons per acre) gave equal or slightly taller plants than did formalin, whereas rates of 0.84 gallons per 100 square yards (and upwards) produced much taller plants than formalin. The data provided show that application of thirty to forty gallons of chloropicrin per acre, applied not less than thirty-five days before sowing, is likely to be a satisfactory means of carrying out partial soil sterilisation of conifer seedbeds.

Residual Effects of Chloropicrin and Formalin

At Fleet, Newton and Benmore, the 1953 chloropicrin experiment was re-sown with Sitka spruce without further sterilisation treatments. The object was to determine the residual effects of chloropicrin, which had been injected in the spring of 1953 at 0.41, 0.62 and 0.84 gallons per 100 square yards, at depths of three to five inches. These were compared with residual effects of formalin applied at five gallons per 100 square yards, and with a control where no sterilising agent had been applied.

Neither chloropicrin or formalin produced any residual effect at Newton. At Benmore there was no significant residual effect for the formalin, but the average of all three rates of chloropicrin gave a highly significant increase in the heights of seedlings. Greater heights were obtained with the higher rates of application. At Fleet, chloropicrin produced significantly smaller seedlings than did either formalin or the control, which themselves did not differ significantly. This happened at all levels of application of chloropicrin. The number of plants produced was in no case greatly affected.

Supplies of Chloropicrin

Comparative trials of imported American chloropicrin and chloropicrin manufactured in a pilot plant in Britain were made at Inchnacardoch, Tulliallan, Bush and Fleet. Both materials were applied by injection to seedbeds at rates of 0.53, 0.84 and 1.05 gallons per 100 square yards. Rate for rate, both products produced Sitka spruce seedlings of similar height growth. The yield of seedlings was also similar. It appears that both products are suitable for soil sterilisation work.

Seedbed Compaction (232.322.6)

The experiment reported in last year's Annual Report was repeated at Inchnacardoch, Bush, Fleet, and Wykeham nurseries.

Last year's recommendation was borne out, namely, that rolling seedbeds before sowing with a twelve-inch diameter roller, weighing from one to four cwt. (112 to 448 lb.), is a satisfactory procedure, and that nothing is to be gained from firming the seed into the bed surface with a light roller or by rolling in the grit. Treatments under test included 'no rolling', and rolling the seedbed before sowing with rollers approximately one foot diameter and weighing one, four and seven hundredweight, firming the seeds into the surface after sowing, with a board pressed by hand, and rolling with a one cwt. roller after the seed had been covered. Resulting crops of seedlings were assessed for speed of germination, and for height and yield of seedlings.

Results at all centres generally confirmed the findings of the previous year, namely, that early germination was accelerated by rolling the beds before sowing, the highest rate of germination being recorded in beds rolled with the heaviest roller.

Only at Fleet were heights of seedlings significantly affected by the initial rolling. At this nursery the seven-cwt. roller produced significantly taller plants than the uncompacted beds, or the beds rolled with a one-cwt. roller. Firming the seed into the surface, and rolling after applying the grit, had no effect on seedling heights at any of the nurseries.

Only at Inchnacardoch and Wykeham were significant differences in yield of seedlings recorded between treatments. At Inchnacardoch the four- and seven-cwt. rollers significantly increased the yield of plants in comparison with uncompacted beds; whereas at Wykeham the reverse was true, viz., the four- and seven-cwt. rollers significantly reduced the yield of seedlings. Although rolling with a seven-cwt. roller also gave satisfactory results, such a roller presents practical difficulties because, unless a large diameter roller is used, the roller produces cracks in the seedbed. Furthermore, it is difficult to manoeuvre and transport. These difficulties outweigh its other slight advantages.

Manuring

Time of Application of Potash and Phosphate Fertilisers (232.322.4)

The final experiments in this series were repeated at Inchnacardoch, Tulliallan, Benmore, Fleet and Wykeham. Treatments consisted of standard dressings of sulphate of potash at 5.21 lb. per 100 square yards (0.40 oz. K_2O per square yard), and of superphosphate at 13.88 lb. per 100 square yards (0.40 oz. P_2O_5 per square yard), applied at three different times, either on the date of sowing, three weeks before sowing, or nine weeks before sowing. Mean heights and total numbers of seedlings were not affected by the date of the treatment. This confirms the findings contained in last year's Report.

From the combined data of the past three seasons' work on the subject, it is concluded that artificial potash and phosphate manures may be safely applied to spruce seedbeds at any time within a period of three months in advance of sowing. Applications made at various times within this period produce seedlings of similar height. Very early applications of fertiliser may not be suitable for species which germinate rapidly, and it is proposed to carry out a similar series of experiments on pines, and also on larches, to test this point.

Time and Method of Applying 'Nitrochalk' to Seedbeds

A third repetition of the experiment concluded this project, which is designed to compare the effect of equal amounts of 'Nitrochalk' applied, at different times and in different ways, to one year Sitka spruce seedbeds. 'Nitrochalk' (15.5 per cent N) was applied, at a rate of 10.2 lb. per 100 square yards, either as (*a*) one-third dressing before sowing with two subsequent top dressings of one-third each at a variety of dates during June, July or August, or (*b*) no initial dressing but as two equal top dressings during June, July, August, or combinations of any two months. The experiment was carried out at Inchnacardoch, Newton, Tulliallan, Benmore and Wykeham.

Benmore was the only nursery where seedlings were significantly taller after 'Nitrochalk' was applied *entirely as top dressings*; at the remaining nurseries there were no significant differences between the two methods.

As in 1953, 'Nitrochalk' applied in July or August as a top dressing produced seedlings which were significantly taller than plants which received all, or part, of the 'Nitrochalk' in June. Exceptions occurred at Newton (where none of the treatments differed significantly for mean heights) and at Wykeham where 'Nitrochalk' applied partly in June or July, and partly in August, produced much taller plants than other combinations of months, or single-month treatments.

The yield of seedlings was not greatly affected by any of the treatments. At some of the nurseries where an early frost was recorded in September, all the plots (including plots which received no 'Nitrochalk') were equally affected by the frost.

These experiments, which have been repeated for three years on a wide variety of nursery sites covering a range of climatic conditions, confirm the statements made in the two previous Reports, namely, that two top dressings of 'Nitrochalk', in either August or July, or one in each month, give the greatest nitrogen stimulus to height growth. 'Nitrochalk', if carefully applied, is safe to use and does not cause losses of plants in Sitka spruce seedbeds. There is no evidence that 'Nitrochalk' increases the chances of early frost damage, even when applied as late as the third week in August.

A similar series of experiments will be started in 1955, using the more frost-tender species, Japanese larch and Douglas fir.

Organic and Inorganic Manuring in Heathland and Woodland Nurseries

The experiment originally designed to compare the effects of greencrop and compost on newly opened heathland nurseries was re-sown with Sitka spruce, at Inchnacardoch. Plots which received compost in 1953 received raw hop waste at 100 lb. per 100 square yards; and plots which received phosphate, potash and nitrogen were re-treated with these manures at the 1953 rates. Results at the end of the growing season indicated that compost and hopwaste manures, and phosphate and potash fertilisers, produced the tallest seedlings. Ground greencropped two years previously showed no beneficial effects, and ground treated with 'Nitrochalk' produced smaller plants than did the plots without 'Nitrochalk'. Phosphate and potash fertilisers increased the yield of seedlings, but other main treatments had no significant effects.

Grist Size of 'Flash' Nitrogen Manure

At Newton, Benmore, Wauchope and Wykeham, five grists (or grinding sizes) of 'flash' (plastic urea-formaldehyde waste) were compared with each other and with 'Nitrochalk'. The 'flash' ranged in size from 16 to 100 mesh, and it was applied and mixed with soil at rates calculated to yield 0.5 oz. N per square yard. 'Nitrochalk' was applied as summer top dressings at rates of 0.25 oz. and 0.5 oz. N per square yard. The measure of success of the treatments was determined by their effect on the height growth and yield of one-year seedlings.

None of the treatments had any significant effect upon the numbers of seedlings. There were no significant differences in the height growth of plants raised on different grists of 'flash' at any nursery, and in general there were no outstanding differences between 'flash' and 'Nitrochalk' (*vide* also *Research Annual Report*, 1954).

It is, therefore, concluded that any particle size of 'flash' within the size limits of 16 to 100 mesh is quite suitable as a nitrogenous manure for conifer seedbeds.

Magnesium Manuring

In part of Inchnacardoch Nursery in 1953, one-year Sitka spruce seedlings showed hard yellowing of the foliage, which is believed to be a symptom of magnesium deficiency in the soil. This site was used for an experiment designed to show the effect, on the growth and appearance of Sitka spruce seedlings, of ground lime and ground magnesian limestone (both at 13.88 lb. per 100 square yards), sulphate of potash at 5.2 lb. per 100 square yards, and magnesium sulphate at 9.26 lb. per 100 square yards, all being applied to the soil before sowing, and magnesium sulphate applied as a two per cent solution foliar spray at 1.6 lb. per 100 square yards.

Magnesian limestone produced plants which were significantly taller than those which received ground lime. Plants receiving magnesian limestone or ground lime were both much taller than plants receiving neither. The increased height following the application of lime is curious, and may be due to traces of magnesium contained in the limestone. Magnesium sulphate also produced increases in height growth, and of the two methods used, basal application before sowing was more successful than spraying on the foliage. Potash had no effect on height growth. Plants raised with magnesian limestone showed the healthiest appearance, whereas plants which received potash were yellow at the end of the year. The experiment is being left for a second growing season in order to observe further developments.

It appears that an application of magnesian limestone at six cwt. per acre is a satisfactory method for correcting magnesium deficiencies in conifer nursery soils.

Seaweed Compared with Hopwaste Manures in Woodland Nurseries

At Inchnacardoch, Teindland and Tulliallan Moor woodland nurseries, an inexpensive proprietary manure consisting largely of ground dehydrated seaweed was compared with the standard hopwaste manure, which is more expensive. The dehydrated seaweed (twenty-five per cent H_2O) was applied at 11.57, 23.14 or 34.71 lb. per 100 square yards (five, ten and fifteen cwt. per acre: the manufacturer's recommended rate is ten cwt. per acre) and the raw wet hopwaste (approximately seventy-eight per cent H_2O) was applied at standard rates of 970 lb. per 100 square yards (twenty-one tons per acre), on the old woodland site at Inchnacardoch and Teindland, and at double these rates on the new site at Tulliallan Moor. These organic manures were either applied singly, or in combination with an initial dressing of artificial fertilisers at standard rates.

In all these nurseries, hopwaste produced very much larger seedlings than seaweed. The seaweed manure at all three concentrations had negligible effects on the height growth of seedlings. Artificial fertilisers produced large increases in the heights of seedlings on the new site at Tulliallan Moor, and also at Teindland, but at Inchnacardoch they had little effect. None of the seaweed treatments had any marked effect on the yield of seedlings, when compared with control, but the hopwaste treatment at Teindland reduced the yield of seedlings in comparison with the seaweed and the control.

This trial has shown that seaweed manure, at least at the rates tested, is not a satisfactory substitute for hopwaste.

Mulching

The experiment on the residual effect of a mulch on production of seedlings was repeated for a third time at Wareham Nursery, Dorset. Mulches of heather, bracken or inert cellulose, applied in May, 1953, were removed before sowing in late April, 1954. Five species were drill sown in each plot. Two species, Japanese larch and western hemlock, responded neither in height growth nor in numbers of seedlings per drill. Corsican pine seed germinated to give significantly more seedlings per drill under all mulched treatments, than it did on control plots; there were no significant differences between mulching treatments, though heather mulch brought about appreciably more seedlings than did either bracken or inert cellulose. There were no differences between heights of Corsican pine seedlings in any treatment.

In Sitka spruce and *Thuja plicata* there were no differences in seedling numbers on any treatments. Heather mulch, however, produced a significant increase in heights of both Sitka and *Thuja plicata* seedlings, and bracken mulch similarly increased heights of *Thuja plicata* seedlings.

These results differ slightly from those of previous experiments in that no depression of growth has arisen this year from inert cellulose mulching. Otherwise there is general agreement that mulching in the year prior to cropping with seedbeds has only a slight beneficial effect on seedling growth.

Long-term Fertility Demonstrations

The large-scale demonstrations at Elvetham Nursery, Bramshill, of the long-term effect on growth and out-turn of Sitka spruce seedlings of three regimes of manuring, was continued into its fifth year. This year, raw hops was substituted for bracken/hop compost.

Height growth in all plots was poor. This is attributed partly to the coldness of the season, and partly to the fact that this was the fifth year of continuous cropping.

ELVETHAM NURSERY, FERTILITY DEMONSTRATION:
ASSESSMENT OF HEIGHT AND PRODUCTION OF SITKA SPRUCE SEEDLINGS IN THE FIFTH YEAR'S CROPPING

Table 3

		Mean Height ins.		Nos. per sq. yard	
No organic or inorganic fertilisers ...		0.44	±0.04	698	±74.4
Raw hops only		0.86		544	
Inorganic fertilisers only		0.98		630	
Raw hops + inorganic fertilisers ...		1.32		608	
Difference for significance	5%	0.12		239	
	1%	0.18		342	

These results agree with those of the two previous years, in which combined inorganic and organic manures brought about the best seedling growth, while numbers per square yard do not differ significantly.

The relationship of seedling numbers from the different treatments has persisted for four years, with organic treatments producing fewer seedlings per square yard. This relationship has also been observed at Wareham in similar experiments. The reason for this is not known, though it has been suggested that organic manures may make the soil more open, and thereby allow surface layers to dry more readily to the detriment of seedlings only partially established.

At Wareham Nursery the demonstration of fertility maintenance under regimes used by the late Dr. M. C. Rayner has been reduced in size, to enable the larger part of the nursery to be used for raising stock for forest experiments. Two sections have been put aside permanently for demonstration of two of Dr. Rayner's regimes. Each section has been divided into four parts, each of which is in a different phase of a four-year rotation of seedbeds (two years), transplants (one year), green crop following winter mulch (one year). In one section bracken-hopwaste compost is used, in the other a pure hopwaste compost. Both sections have been productive, though growth is poorer than in previous seasons. Plants on the pure hopwaste compost showed symptoms of deficiency of potassium (a reddening of foliage of seedlings), while plants on bracken-hopwaste compost were healthy.

In Scotland, the long-term fertility demonstration at Teindland woodland nursery continued into its fifth year. Results in both the lodgepole pine and Sitka spruce sections confirmed the results obtained in 1953, viz., that the most successful treatments are hopwaste-plus-artificial fertilisers, and hopwaste alone.

followed by artificial fertilisers alone. (See Table 4.) Results prior to 1953 showed that 'artificial fertilisers alone' was the most outstanding treatment.

TEINDLAND WOODLAND NURSERY FERTILITY DEMONSTRATION: END OF FIFTH YEAR HEIGHT AND NUMBER PRODUCTION FIGURES FOR SITKA SPRUCE AND LODGEPOLE PINE ONE-YEAR SEEDLINGS

Table 4

Treatment	Sitka spruce			Lodgepole pine		
	Mean Hts. in ins.	Total Nos. per sq. ft.	% over 1½ in. tall	Mean Hts. in ins.	Total Nos. per sq. ft.	Usable seedlings over 1½ in. tall
No manures or hopwaste...	0.83	120	3	1.27	56	20
Artificial fertilisers only ...	1.67	116	51	1.77	77	61
Hopwaste only	1.75	113	55	2.13	56	82
Artificial fertilisers and hopwaste	1.93	100	64	2.18	57	82
Standard error ±	0.045	6	—	0.07	7	—
Difference for significance 5%	0.15	not	—	0.27	not	—
1%	0.23	sigt.	—	0.40	sigt.	—

At Newton the long-term demonstration of greencrop, partial soil sterilisation, compost and artificial fertilisers, was continued by leaving the first crop of Sitka spruce seedlings to grow for a second year. A height assessment of these plants showed different results from those obtained the previous year, when they were one-year seedlings. At that time artificial fertilisers had produced the tallest plants. Plants raised on compost were very much better at the end of the second year. It is thought that this may be due to delayed breakdown of the compost in the soil, or to the lower density of seedlings and the consequent greater abundance of nutrients per plant.

At Fleet a similar demonstration was sown for the first time, and showed quite clearly that ground previously greencropped and subsequently treated with formalin produced much taller seedlings than any of the other treatments.

Irrigation by Overhead Spraying (232.325.1)

Trials of watering by an overhead sprayline sprinkler continued into their fifth year at Kennington. Two watering regimes were tested, one in which water was applied whenever the soil moisture deficit exceeded 0.5 inches, and the other in which water was applied whenever the deficit exceeded 1.5 inches. Sufficient water was prescribed to bring the deficit down to zero. The season was wet and cool, and rainfall was well distributed from the middle of May onwards. There was, however, a marked drought in April and early May.

The more frequent irrigation treatment produced an appreciable response in height growth of Sitka spruce seedlings, while the response to the less frequent irrigation was only slight.

On the margins of the experiment, in areas where irrigation falls less evenly, plots of Japanese larch, Douglas fir, Corsican pine and western hemlock were sown. Irrigation appreciably increased growth of Douglas fir and Japanese larch, but did not affect Corsican pine or *Thuja plicata*. At the beginning of the season the pH of sections under irrigation was measured and recorded. The areas under irrigation had an appreciably higher pH than control areas (Control, 5.2; Irrigated area after four years irrigation, 6.0 to 6.2). This difference is attributed to the lime content of irrigation water. By calculation from water analysis figures, over the period of the experiment in the heaviest treatment, the equivalent of 8.5 cwt. of soluble CaO per acre had been applied in irrigation water.

A large scale irrigation trial was repeated at Kinver nursery, the object being to test, in a Conservancy nursery, the response by seedling germination and growth to the more favourable of watering treatments tested at Kennington (i.e., the application of water whenever the soil moisture deficit exceeds 0.5 inches). The season at Kinver was particularly wet; rainfall in the four months June to September was 22.94 inches, and irrigation was only applied on four occasions during the season. The species under test, Sitka spruce, showed no response to irrigation in germination speed or numbers at end of season, nor in height growth.

Undercutting Seedbeds (232.326.3)

Experiments on undercutting were continued at Bramshill and Markham Oak (Alice Holt) nurseries in Hampshire; the range of species was extended to include oak and beech. Experiments laid down in spring, 1953, were lifted and plants put into the forest. Examination of roots from these experiments showed that plants undercut in August, 1953, or in March and April, 1954, at depths of two or four inches, produced a desirable root form with dense fibrous growth in the upper soil layers. The shoot length noted after these treatments was small. Undercutting later in the year gave rise to plants with larger shoots, but fewer and smaller lateral roots. Undercutting at six inches depth gave seedlings which had some increase in root fibre at the point of cutting, but which were inferior in root form to seedlings undercut at two or four inches. Their shoots were, however, less checked. (Photo 6 shows undercutting equipment.)

Assessments, at the end of 1954, of the experiment on density of sowing and depth of undercutting, laid down in 1951 and planted out in King's Ride, Bramshill Forest, in 1953, show that one-plus-one stock survived best, that second-year seedlings had survived poorly and were not growing well, while undercut stock (one-u-one) is intermediate in position; its growth is satisfactory but survival by no means as good as stock planted as one-plus-one transplants.

The first assessments of the similar experiment laid down in 1952, and planted out at Easthampstead Park, Bramshill, in 1954, show the survival of plants put out as second-year seedlings is significantly lower, and survival of one-plus-one transplants is appreciably lower, than is that of undercut plants (one-u-ones). Survival in this experiment is considerably better than in the previously mentioned experiment.

Studies of root growth were commenced in 1954 as a complement to the undercutting experiments. Seedlings of Corsican pine and Douglas fir were raised from seed in boxes with glass sides, and the root growth visible through the sides of the boxes was measured at fortnightly intervals. No major fluctuations in growth rate were observed during the summer, but growth of roots continued into the beginning of November. The growth of the same seedling roots will be observed throughout their second season.

In Scotland, at Newton and Fleet, plants from the 1953 Scots pine and Japanese larch undercutting experiment were lifted, and assessments were made on samples for shoot length, shoot weight, root weight, root collar diameter and number of secondarily thickened roots over two inches in length. The experiment was designed to compare the effect of raising seedlings at sixteen, thirty-two and forty-eight per square foot, and also the effect of undercutting horizontally at two, four or six inches below ground level in either August of the first year, or

March, April, June, or July in the second year. At Newton, seed was drill-sown and lateral root cutting also took place in the various months, whereas at Fleet seed was broadcast sown and only undercutting was carried out.

Undercutting at depths between two and six inches did not greatly affect any of the factors used for assessment; but there was a trend showing that the shallower the cut the greater the reduction in shoot length, and the greater the root weight.

The date of undercutting affected the pines more than it did the larches at Newton, but not at Fleet, and it was clear that undercutting in August the first year, or in March or April the second year, reduced shoot lengths and increased root weights more than did the June or July treatments.

Among sowing densities it was abundantly clear, for both species, that sixteen plants per square foot (approximately lining-out density for obtaining one-plus-one transplants) produce the greatest root and shoot weight, root collar diameter, and number of secondarily thickened roots.

It appears from these two experiments that undercutting at a depth of two to four inches in August the first year, or March to mid-April the second year, at densities of sixteen to thirty-two plants per square foot, produces the most balanced type of undercut seedling.

Plants from these experiments have been put out in the forest so that we can obtain information on their survival and growth, for comparison with two-year seedlings and one-plus-one transplants.

Temporary Storage of Seedlings (232.324.1——084.4)

A problem in heathland nurseries, particularly in the north, is the lifting and dispatch of large quantities of seedlings in spring. Lifting the plants in the winter months would overcome the problem, but suitable methods of storing the plants will have to be found if such a practice is started.

In an attempt to find the answer to the problem, one-year seedlings of lodgepole pine, Japanese larch and Sitka spruce, raised in Teindland woodland nursery, were lifted at monthly intervals from November to March, and stored either in bundles or else loosely, both in boxes under the shelter of a twenty-five-year-old pine wood, or sheughed (heeled-in) in the nursery, or else stored in boxes in a cool chamber (an old salmon ice house). The plants were subsequently lined-out at Newton nursery in April. Assessments of usable plants in autumn showed that bundled plants of lodgepole pine and Sitka spruce had kept better than unbundled plants, although there was no difference in the size of the survivors. Differences between bundled and unbundled Japanese larch plants were negligible. In addition, it was found that storing plants in boxes in the forest was the least successful treatment for all three species. Lodgepole pine and Sitka spruce lifted in January and February survived best, and the percentage survival was significantly greater than that for plants lifted in March, November and December. Japanese larch plants lifted at any time from November to February all stored equally well, while those lifted in March suffered rather higher losses but grew taller.

Handling of Plants

At Elvetham Nursery, Bramshill, an experiment was carried out comparing the effect on survival after lining-out, of materials designed to reduce transpiration from foliage. Four materials were compared, each at three dilutions. The materials, polyvinyl latex, lanolin emulsion, paraffin wax emulsion and clay slurry. Materials were applied to plants when bundled for heeling in; bundles were dipped (foliage only), heeled in overnight, and then lined out. The condition of plants before treatment was poor, and percentage survival was variable inside the various treatments, so that the effects of experimental treatment were masked.

There were, however, indications that clay slurry significantly reduced survival, while lanolin treatments appreciably reduced survival. There were no significant differences in the survival between the different dilutions of any material tested.

Weed Control in Seedbeds

(*a*) Pre-emergence Weed Control with Mineral Oils (232.325.24)

At Kennington and Ampthill nurseries, the effects of Shell T.V.O. and Shell high aromatic oil on seedbeds of Sitka spruce and Corsican pine were compared. Both oils were applied as pre-sowing, as post-sowing*, and as pre-emergence* sprays, at rates of twenty-five, fifty and 100 gallons per acre.

On Corsican pine beds, all spray treatments significantly or appreciably increased seedling heights over those on control plots; no treatment affected seedling numbers of Corsican pine.

Applications of high aromatic oil at 100 gallons per acre significantly reduced numbers of Sitka spruce seedlings.

Weeding times were significantly reduced by all applications at 50 and 100 gallons per acre, and also by the high aromatic oil applied at 25 gallons per acre as a pre-emergence spray.

At Kennington nursery a comparison of the effects, on seedling growth and survival, of pre-emergence oil sprays on three seedbed covering media, namely, St. Austell grit, Bedford sand and Newborough grit, was made. Vaporising oil was applied, at rates of 60, 90 and 100 gallons per acre, to seedbeds sown with western hemlock, *Thuja plicata*, Lawson's cypress, Douglas fir, Japanese larch and Norway spruce.

Germinations of hemlock and *Thuja plicata* under all coverings was poor, and insufficient to provide a basis for any conclusions on responses to treatments.

Newborough grit very significantly reduced the numbers of Japanese larch, Douglas fir and Lawson's cypress, as compared with Bedford sand. St. Austell grit had no effect on numbers of Douglas fir and Japanese larch, but significantly reduced crops of Lawson's cypress, as compared with Bedford sand. Numbers of Norway spruce seedlings were high in all plots.

There was no interaction between types of grit cover and oil sprays. Sprays had no effect on growth or survival of any species, except on Japanese larch, for which species seedling numbers were significantly reduced in all plots receiving 120 gallons of vaporising oil per acre.

(*b*) Pre-emergence Weed Control with Chemicals

At Kennington nursery the effect on growth and survival of Sitka spruce, Japanese larch and Corsican pine seedlings, and on weed growth, of sprays of pentachlorphenol (P.C.P.), and of isopropylphenylcarbamate (I.P.C.), were compared. Each material was applied as a spray three days before sowing, four days after sowing, and three to four days before estimated emergence of seedlings. P.C.P. was applied at one, two and four lb. per acre, and I.P.C. at two, five and ten lb. per acre.

P.C.P. had only a slight effect on production of seedlings and on weeding times. Sitka spruce seedlings were significantly reduced in number on plots sprayed before sowing at two and four lb. per acre. Pre-sowing spray at four lb. per acre very significantly reduced numbers of Japanese larch. There were no

* A *post-sowing* spray is applied just after sowing, whereas a *pre-emergence* spray is applied 2–3 days before the seedlings are expected to emerge.

other significant effects on tree crops from P.C.P. The effect of P.C.P. on weeding times was slight. Only in one treatment, on one species, was there a significant reduction in weeding times, namely where P.C.P. was applied as a pre-emergence spray at four lb. per acre to beds of Sitka spruce.

I.P.C. produced appreciable or significant reductions in seedling numbers when applied at ten lb. per acre, in pre-sowing and pre-emergence treatments, on all species. Corsican pine was particularly susceptible to this material, and seedling numbers were reduced appreciably or significantly in all treatments except the lightest (two lb. per acre), when applied before and after sowing. Control of weeds by I.P.C. was good, significant or very significant reductions of weeding times being obtained in all treatments, except in the pre-emergence treatments on Sitka spruce, where for some obscure reason no significant weed control was obtained with any treatment.

(*c*) Post-Emergence Weed Control with Mineral Oils

At Kennington nursery, an experiment comparing the effect on seedlings of Sitka spruce, Douglas fir, Japanese larch, Corsican pine and *Thuja plicata* of Shell weedkiller 'W', applied at ten gallons per acre every six days, at twenty gallons per acre every twelve days, and at forty gallons per acre every twenty-four days after emergence of seedlings, was carried out. In all species, there was no significant effect from any treatment on seedling numbers. In Japanese larch and Sitka spruce, there was an appreciable reduction of height of seedlings, where treatment of forty gallons per acre of weedkiller had been applied. The height of *Thuja plicata* seedlings was appreciably reduced on plots receiving ten gallons per application.

At Kennington nursery, the effect of post-emergence applications of Shell weedkiller 'W', on seedlings of Sitka spruce and Corsican pine, was compared with the effect of two experimental oils, Shell experimental white spirit and Esso experimental oil. Oils were applied at ten, twenty and forty gallons per acre.

None of the oils, at any rates of application, had any significant effect on seedling numbers or heights. Weeding times were significantly reduced by applications of forty gallons per acre, and appreciably by applications of twenty gallons. Applications of 10 gallons per acre had no significant effect on weeding times. There were no significant differences between the effects of each oil.

At Glenfinart and Tulliallan nurseries, Shell weedkiller 'W' was compared with a cheaper substitute Shell weedkiller 'W AG 2153' on first-year seedbeds of Scots pine, lodgepole pine, European larch, Sitka spruce and Norway spruce. Both chemicals were used as post-emergence sprays, at rates of 0.21, 0.42 and 0.62 gallons per 100 square yards (ten, twenty or thirty gallons per acre). Five applications were necessary at Glenfinart, whereas only four applications were necessary at Tulliallan.

When comparing similar dosages of weedkiller, it was consistently found that Shell 'W' gave highly significant reductions in weeding times. There was no significant difference between equivalent rates of the two products as far as the numbers of tree seedlings were concerned, and only in one case were there significant height differences. These were recorded in the Norway spruce section at Tulliallan, where Shell 'W AG 2153', at thirty gallons per acre, resulted in significantly smaller seedlings than Shell 'W' applied at a similar rate.

Both products, if applied at the heaviest rate, when compared with the control and with the lowest rate, led to lower heights and numbers of seedlings. These differences in the height of the seedlings were usually significant in all species. Only in Norway spruce did the heaviest rate of application significantly reduce the number of plants remaining at the end of the season.

It appeared that the Shell 'W AG 2153' was not an efficient substitute for Shell 'W', and it did not appear possible to compensate for its poorer weed killing properties by increasing the rate of application.

(*d*) Post-Emergence Weed Control with Chemicals

The effect of 2,4-dichlorophenoxyethyl sulphate (S.E.S.) on weeds and on six species of seedlings, Sitka spruce, Japanese larch, western hemlock, *Thuja plicata*, Corsican pine and Douglas fir, was tested at Kennington nursery. S.E.S. was applied in solution at rates of one, two and four lb. per acre, each in fifty gallons of water per acre. The material, S.E.S., is inactive in this form, but is oxidised in the soil to give 2, 4-dichloro-phenoxyacetic acid (2, 4D). The 2, 4D is thus available in the soil for uptake by plants. This experiment was to test the theory that germinating weeds would be susceptible to these low concentrations of 2, 4D in the soil, whereas the established seedlings would not be harmed.

At the end-of-season assessments, there was a significant decrease in the numbers of seedlings of Corsican pine in all S.E.S. treatments, of Douglas fir in plots treated with four lb. S.E.S. per acre, and of Japanese larch in plots treated with two and four lb. S.E.S. per acre. On plots of Sitka spruce treated with two and four lb. of S.E.S., there was an appreciable increase in seedling numbers, while on the hemlock plots, there was no response.

Heights of Sitka spruce and Japanese larch seedlings were significantly lower on treated areas, while heights of the remaining species under test showed no difference following treatment. Weeding times were not affected by any treatment.

At Ampthill, the effects of undecylenic acid and ferrous sulphate, applied as post-emergence sprays to seedlings of Norway and Sitka spruce, were compared. Undecylenic was applied in emulsion with water at sixty gallons of 0.25, 0.5 or 1.0 per cent acid per application.

Treatments with 1.0 per cent undecylenic acid significantly reduced seedling numbers and heights of both species, while 0.5 per cent treatment appreciably reduced numbers and heights of Sitka spruce. Weeding times were significantly or appreciably reduced by all treatments, except the 0.25 per cent applications on plots of Norway spruce. Weeding times were reduced most on the plots treated with 1.0 per cent solution (as expected); the reduction was between thirty-five and forty per cent of the time necessary to weed the control plots.

Ferrous sulphate was applied, dissolved in water at sixty gallons of five, fifteen or twenty-five per cent solution per application. Seedling numbers and heights of Sitka spruce were appreciably or significantly reduced by fifteen and twenty-five per cent solution treatments. Norway spruce seedlings were unaffected by any treatment. Weeding times were significantly reduced on plots of Sitka spruce, the reductions being of the same order as those resulting from undecylenic acid treatments; weeding times on plots of Norway spruce were unaffected by treatment.

(*e*) 'User Trials' of Pre- and Post-Emergence Applications of Mineral Oils

Trials of the effectiveness of applications of vaporising oil for pre-emergence, and of white spirit for post-emergence, weed control were carried out at nine nurseries, selected to cover a range of soil and climatic conditions and degrees of weed infestation. Four species, Japanese larch, Sitka spruce, Corsican pine and Douglas fir were sown at each centre and four treatments compared: hand-weeding, vaporising oil applied as a pre-emergence spray at sixty gallons per acre plus subsequent hand-weeding, vaporising oil at sixty gallons per acre plus white spirit applied as a post-emergence spray at twenty gallons per acre, and vaporising oil at sixty gallons per acre plus white spirit at forty gallons per acre.

At all centres, seedling numbers and heights of Corsican pine were not significantly affected by any oil treatment, while numbers and heights of Japanese larch, Douglas fir and Sitka spruce were significantly or appreciably reduced in plots receiving vaporising oil and forty gallons of white spirit per acre. In weedy nurseries (e.g., Eversley, Bramshill), seedling numbers on hand-weeding plots were very significantly lower than on all others.

Weeding times were significantly reduced by the pre-emergence sprays and post-emergence sprays. Post-emergence sprays at forty gallons per acre per application were significantly more effective in weed control than were post-emergence sprays at twenty gallons per acre.

Weed Control in Transplant Lines (232.325.24)

Machinery has been developed for spraying weedkillers on transplant lines. (See Photo 7.)

Experiments were carried out at Bramshill and Kennington comparing the effect of repeated applications of vaporising oil and white spirit on Sitka spruce, Douglas fir, Corsican pine, Japanese larch and *Thuja plicata* which had been moved into the lines as one-year-old seedlings.

At Bramshill, oils were applied as inter-row sprays at sixty and 120 gallons per acre. There were six treatments, in each of which sprays were applied at monthly intervals, the first spray application in each treatment being separated by one month. Thus, the second spray in the first treatment was applied in late May, at the same time as the first spray of the second treatment, and so on. The sixth treatment received only one spray, in late September.

In no treatment was there any reduction in growth or survival. Plants in all treatments looked healthy at the end of the season and needle-scorch was negligible. Very significant reductions in weeding were obtained from all early treatments, there being no significant differences between the different oils or rates of applications. Treatments commencing later produced progressively smaller responses, which were appreciable even in the latest treatments.

At Kennington, the effects on tree growth, of overall and inter-row applications, of vaporising oil and white spirit at 60, 120 and 240 gallons per acre were compared. Sprays were applied at monthly intervals, commencing either in April or in July, to Sitka spruce, Douglas fir, Corsican pine, Japanese larch and *Thuja plicata* put into the lines as one-year-old seedlings.

Applications of either of the oils, at sixty gallons per acre, had no effect on height growth or survival of the crop. Inter-row applications of 120 gallons per acre of vaporising oil, commencing in April, produced an occasional contortion of stems of Japanese larch and some death late in the season in Sitka spruce. Inter-row applications at 120 gallons per acre of vaporising oil, commencing in July, and of white spirit commencing in both April and July, did not reduce growth; only slight scorching of lower needles was observed.

Overall applications of both oils, at 120 gallons per acre, produced significant reductions in height growth, moderate to severe scorch to foliage of all species, and death of leaders of Japanese larch, Douglas fir and Sitka spruce. Damage by white spirit was appreciably less than that by vaporising oil. Inter-row sprays of vaporising oil, at 240 gallons per acre, caused appreciable or significant reductions in height growth in all species, and in numbers of *Thuja plicata* and Douglas fir. The lower foliage of all species was markedly scorched. Contortion of stems of Japanese larch occurred where treatments commenced in April. Inter-row application of white spirit, at 240 gallons per acre, produced deaths in *Thuja plicata* and Corsican pine, and distortion of stems of Japanese larch. Damage was appreciably less than that brought about by vaporising oil at the same rate.

Overall applications of both oils, at 240 gallons per acre, produced very significant reductions in height growth and survival of Japanese larch, *Thuja plicata*, Douglas fir and Sitka spruce. Scorch to foliage was slight in Corsican pine, but moderate to severe in other species. Damage was less severe in treatments commencing in July. Vaporising oil caused considerable stem distortion in Japanese larch.

No critical observations were made on weed control in these Kennington experiments, as the weed population was small. Satisfactory control was obtained in all treatments.

Weed Control on Fallow Land (232.322.1)

The experiments laid down on fallow land at Wytham, Oxford and Bramshill nurseries in 1953 were cropped with seedbeds and transplant lines in 1954. In 1953, treatments were: T.C.A. (Sodium trichloracetate) at 15, 30, 60, 120 and 240 lb. per acre; C.M.U. (Chlorophenyldimethylurea) at 2.5, 5, 10, 20, and 40 lb. per acre; sodium chlorate at 75, 150, 300 and 600 lb. per acre; 2, 4-D (2, 4-dichloro-phenoxyacetic acid) at 1, 3 and 6 lb. (acid equivalent) per acre; 60 lb. T.C.A. plus 3 lb. 2, 4-D per acre; 10 lb. C.M.U. plus 3 lb. 2, 4-D per acre; and untreated control. Observations on weed growth during the period of fallow showed that no weed control had been obtained from treatments with 2, 4-D, so that these were omitted from the 1954 cropped area.

Crops raised on plots which received T.C.A. or sodium chlorate at all rates, and C.M.U. at 2.5 and 5 lb. per acre, were unaffected by treatment. Crops on plots receiving higher rates of C.M.U. were appreciably or significantly reduced in height, and also in numbers surviving. Douglas fir was exceptional and was not significantly affected, even on plots which received 40 lb. C.M.U. and on which no other plants, either weed or crop, were able to survive. This ability of Douglas fir to survive in conditions where other species cannot is not readily accounted for.

Weed growth was significantly (or very significantly) reduced only on plots receiving C.M.U. at 10 lb. per acre and more. No other treatment had any effect on weed growth in the following year except at Wytham, where T.C.A., at 240 lb. per acre, significantly reduced weed growth. This reduction was, however, by no means as marked as that from C.M.U. treatments.

At Alice Holt and Eversley nursery, Bramshill, further experiments on control of weeds in fallow land were laid down, comparing C.M.U., T.C.A. and P.D.U. (Phenyldimethylurea). P.D.U. is said to be as toxic to germinating weeds as C.M.U., but to be less persistent. Observations on weed growth during the year showed no visible differences between plots with C.M.U. and P.D.U. Both experimental areas will be cropped in 1955.

Control of Weeds by Electricity (232.325.29)

A portable apparatus developed by the Electrical Research Association for thinning of sugar beet was obtained, and its ability to kill weed species prevalent in nurseries was tested. The apparatus consisted essentially of accumulators, a transformer, and a vibrator; it delivered an alternating current of ten milliamperes at an electromotive force of 1,200 volts.

Weeds were treated by being touched by a probe leading from the apparatus, with an insulated handle. Plants were either touched at the heart or at the extremities.

Results showed that the current killed all tissues through which it passed. However, when dealing with the larger weeds, the current passed through one side of the plant only and the remainder survived, so that flowering and seeding continued. Similarly, to kill large grass plants, it was necessary to touch all stems. Those that were missed survived. It became apparent that while small weeds were killed instantaneously, these same weeds would have been killed by application of mineral oil weedkillers. Larger weeds were not necessarily killed unless an appreciable time was spent in touching all sides of a plant, which operation would take longer than careful removal by hand.

Miscellaneous

Bird Repellents (232.327.3)

At Bramshill, three proprietary makes of bird repellent, applied as seed dressings, were tested on seed of Corsican pine and compared with standard red lead seed dressing, and with wire netting (mouse netting) laid about three inches above and over the full width of seed beds.

Before and during germination no bird damage was observed in any treatment. Soon after general germination, serious damage was done by larks which were observed working up the beds eating cotyledons and terminal bud of seedlings. Where the bud was not removed the seedlings survived.

Only in the plots covered with netting was protection adequate. There were no significant differences between any of the other treatments. End-of-season assessments showed 320 seedlings per square yard in netted plots and 84 to 125 seedlings per square yard in the other plots. The mean height of seedlings on netted plots was significantly higher than on all other plots. This difference was attributed to the action of the birds in eating the larger germinated seedlings and weakening others by removal of cotyledons.

Seedbed Covering Media for Abies grandis. (232.323.5)

An experiment to compare soil and grit covers at depths of 0.25, 0.5 and 0.75 inches over *Abies grandis* seed was carried out at Tulliallan Moor, Wauchope and Bush nurseries. The experiment was marred at Tulliallan and Wauchope by very low germination of seed. At Bush nursery, where the highest yields of seedlings were obtained, it was shown that soil and grit covers gave similar yields of seedlings, and also seedlings of similar height; but that the three-quarter inch cover produced almost double the number of seedlings than did the quarter-inch cover. The half-inch cover produced an intermediate yield. The different depths of cover did not result in any significant differences in mean heights of seedlings.

Soil Conditioners (232.322.5)

The areas of seedbed on a heavy soil at Ddwylig Nursery, St. Asaph, N. Wales, which in 1952 and 1953 were treated with 'Krilium' soil conditioner, were resown in 1954 without further treatment. At the end of the growing season, there was a significant reduction in numbers of seedlings of Scots pine and Sitka spruce on plots treated with 'Krilium'. In the case of Scots pine, the treated plots contained forty-five per cent fewer seedlings than did the controls. There was no significant effect on seedling numbers of Japanese larch, Norway spruce or Douglas fir, nor was there any effect on the height growth of any species.

The soil itself, where treated with 'Krilium', showed a marked increase in crumb formation and workability.

Nursing Effects in Transplant Lines (232.324.9)

At Alice Holt an experiment was laid down to compare growth in transplant lines of Sitka spruce and western hemlock, when in mixture, compared with growth of the same species in pure blocks. This experiment arose out of observations that hemlock and Sitka spruce appeared to have a mutually beneficial effect when growing in adjacent blocks. Mixtures containing either alternate lines of each species or alternate species in each line, were compared with pure blocks. There were no significant differences in height growth of either species, whether pure or in either type of mixture. The differences in survival were small, and overall survival was high. However, in the mixture with alternate species in each line, survival of hemlock was significantly higher, but survival of Sitka spruce appreciably lower, than in other treatments.

Maleic Hydrazide as a Growth Inhibitor

Further trials were carried out to find the effect of a spray of 0.2, 0.15, 0.1 and 0.05 per cent solutions of maleic hydrazide in water, on the subsequent rate of growth and date of flushing of first-year seedlings of Scots pine, Japanese larch, Norway spruce and Douglas fir, at Newton nursery; and of Norway spruce only at Tulliallan and Fleet nurseries.

As reported in 1953, application of maleic hydrazide did not affect the date of flushing of any species at any of the nurseries. It does not appear that the reduction in subsequent growth is caused by alteration in the time of flushing.

The heaviest dose of maleic hydrazide produced a highly significant check to the rate of growth of Scots pine, while the 0.15 per cent dose significantly retarded growth. Only the heaviest dose significantly reduced the growth of Japanese larch. Lighter doses had no effect on any of the species. The growth of Norway spruce or that of Douglas fir was not significantly affected by maleic hydrazide at any level of application.

It appears that the growth-reducing effect of maleic hydrazide at the concentrations employed during experiments over the last four years has been erratic. There is evidence that the heaviest rate may malform the growth of the plants, although this effect may only be transient.

PROBLEMS OF AFFORESTATION

By R. F. WOOD and J. W. L. ZEHETMAYR

Pilot Plots on Difficult Sites in the North (232.11:233)

GROWTH in the pilot plots planted in 1946-49 at Inchnacardoch, Inverness-shire, Strathy, Sutherland, and other sites continues to be reasonably promising. It is becoming apparent, however, that, in some of the plots planted since then, conditions are, as was intended, even more difficult, and that establishment will not be achieved so easily as in the earlier set. At sites such as Forss and Skiall, Caithness, it is clear that exposure is the dominating factor. The trees have grown beyond the shelter of the plough ridges and vegetation, but are not yet giving mutual shelter, so that every winter and spring brings the risk of almost complete defoliation. The two main species on which reliance has been placed, lodgepole pine and Sitka spruce, are showing remarkable recovery from such blasting, but most of the other species included show little prospect of growing. The past winter has caused severe damage to certain plantations, and a very high death rate, in one of the four plantations made last year in Hoy, Orkney Islands. While assessment is not yet complete it is clear that in the most exposed site on the most fertile soil eighty-five per cent of the plants have died, whereas in the relatively sheltered plantation, on 'unplantable' deep peat, the loss is but fifteen per cent.

The work of repairing these plantations has been completed, but this has resulted in certain other plots planned for this year being held over. Meanwhile several new trial plantations have been completed, including one at Ullapool, Wester Ross (an eight-acre plot in an exposed coastal site); and two at Carrick and Glentrool Forests, Ayrshire and Kirkcudbright (five-acre plots completing a chain of four over a pass which runs to 1,400 feet).

In the same category of work comes a series of high elevation plots of one acre planted by South (Scotland) Conservancy to Research Branch specifications at the Garraries Forest, Kirkcudbrightshire. These form a chain over the Rhinns of Kells at 1,500, 1,750 and 2,000 ft., on the west-facing, and at 1,750 ft. on the east-facing slope. Much of the land at high altitude in the area is of considerably better quality than the lower slopes.

Another small shelter plantation has been undertaken in the Shetland Islands on fair grazing land; on the Reay Estate, in the far north-west of Sutherland, two small plots have been completed in co-operation with the Pulford Estates company.

The success of all these plots appears to turn on the balance between soil conditions and exposure, provided that soil preparation, planting and selection of species have been correct. Experience has enabled the chances of success on various vegetation and ground types to be estimated with some accuracy; but the problem remains of gauging exposure and finding how far shelter compensates for a poor type of site. To this end a method has been developed of calibrating sites for exposure by the degree of tattering exhibited by unhemmed linen flags of standard pattern. A series of eighteen pilot plots, extending from Shetland to Fort Augustus and Aberdeenshire, was chosen to include as controls the experimental areas where trees have been induced to grow on difficult sites, and also many of the recently planted pilot plots. After one year's trial there would appear every hope that a correlation can be established between exposure, as judged by the rate of tattering, and relative growth of the trees. The stage appears to have been reached in this project when a pause must be made to await the growth of the trees, and to determine the level of exposure beyond which further trials on the present lines become pointless.

Afforestation of Special Types of Land in England and Wales (232.11:233)

A second season's work has been carried out at Croft Pascoe (Goonhilly Down), an interesting heath overlying serpentine on the exposed Lizard Peninsula of Cornwall. A wide range of species is now under trial on this site, including Monterey pine (*Pinus radiata*), maritime pine (*P. pinaster*), Corsican pine (*P. nigra* var. *calabrica*), Austrian pine (*P. nigra* var. *austriaca*), mountain pine (*P. mugo*), *Pinus peuce*, lodgepole pine (*P. contorta*), Sitka spruce (*Picea sitchensis*), *Picea glauca*, *P. omorika*, *P. rubens*, western hemlock (*Tsuga heterophylla*), noble fir (*Abies procera*), Lawson's cypress (*Chamaecyparis lawsoniana*), Japanese cedar (*Cryptomeria japonica*), Monterey cypress (*Cupressus macrocarpa*), red oak (*Quercus borealis*), *Nothofagus procera*, *N. obliqua* and a few eucalypts. The more speculative species have been planted in mixture with lodgepole pine.

Other subjects of investigation at Croft Pascoe include: manuring (nitrogen, phosphorus, potassium and calcium); position of planting on furrow; nursing, with both pine and broom; and protection of direct sowings with bituminous covers. The direct sowings of the previous year largely failed because wood mice (*Apodemus sylvaticus*) ate the seeds.

At Newborough Warren, Anglesey, where dune fixation is in progress, a trial of various bituminous preparations has been carried out. These are sprayed on to the surface after sowing or planting, with a view to temporary fixation of the moving sand till such time as the tree crop can take over. Successful use of this technique has been reported from Russia.

Unsatisfactory or Checked Plantations (237)

Preparatory surveys were made in the Welsh forests of Tarenig and Hafren, where spruces and other species have failed locally, and experimental work to determine the causes appears to be called for. One of the main difficulties on certain of the sites is that the ground is too rough or steep for ploughing.

Experimental plantations on recently reploughed land in the Cornish forest, Wilsey Down, appear to be satisfactorily established. On one section, where Sitka spruce has failed widely, broom has produced very striking responses: early phosphate effects are very noticeable. It is hoped that a nurse (coastal *Pinus contorta* or broom), together with adequate manuring, may succeed in bringing about adequate suppression of the difficult vegetation on this site, which, in conjunction with extreme exposure, seems to exercise an especially adverse effect on young plantations.

Checked plantations at Wareham Forest, Dorset, have been surveyed with a view to experiments on the amelioration or replacement of existing crops on this particularly difficult heath.

Ploughing (232.216)

Trials of an Australian stump-jump disc plough have been started on heathland types. The object is to establish areas of completely ploughed land in contrast to the large areas of single furrow ploughing planted in the last fifteen years. The latter carries an inherent risk of directional development of roots concentrated along the furrows, and thus of windblow from gales at right angles to this direction. While complete ploughing has been used experimentally for almost thirty years, there has never before been a machine available capable of carrying out complete ploughing on an economic scale. It was hoped that this machine would fulfil this purpose, but trials so far have been disappointing.

Manuring in the Forest (232.425.1)

The trials of triple superphosphate as a possible alternative to ground mineral phosphate continue. The saving of two-thirds in weight for equal dosage is important from the forestry angle, where transport probably accounts for half the cost of manuring. The feared increases in losses through use of this highly soluble manure occurred in only one of a dozen experiments planted last year, but the season was so wet that this cannot be regarded as reassuring, and a further set of trials has been laid down.

MIXTURE EXPERIMENTS

By G. D. HOLMES and R. LINES

(235.5)

A START has been made on a series of two-species mixtures (to be grown to maturity as such), with pure crops of each of the two species as controls. The object is to compare such long-term effects as the yield and quality of the produce, and the effects of the mixtures on the site as compared with each species grown in pure plantations. Each experiment has three replications of four treatments arranged in a 'Youden square', the treatments being each species pure, with duplicate plots of the mixture. The latter will allow differential thinning treatments to be carried out later.

This season's experiments of this nature using Sitka spruce and western hemlock (*Tsuga heterophylla*), have been laid down at one Scottish and four

Welsh forests. It is proposed to restrict this series of experiments to species which we have reason to think can be maintained easily in mixture and which appear to offer some possible advantages when managed as such.

At Gisburn Forest in the West Riding of Yorkshire a large long-term experiment in pure and mixed crops was planted. This experiment has been planned in conjunction with the Nature Conservancy, who are to make a special study of the soil changes under the different crops. It is also proposed to analyse samples of the plants at the time of planting, and, later on, the material obtained from thinnings and brashings, for their mineral content. The area was intensively sampled before planting to discover the initial pH range of the soil. There are ten treatments in three randomised blocks, comprising pure plots of Scots pine, Norway spruce, common alder and ash/oak; each species being combined in a mixed plot with one of the remaining three species to give six different mixtures. (Ash/oak counts as one species. The one which is less successful will be cut out.) In addition, each of the three randomised blocks will have one plot which is left unplanted, and another which is not planted but is grazed by sheep.

Each plot is half an acre in area, and it is hoped that it will be possible to keep the experiment under observation for at least one rotation and possibly more. Sample plots will later be established in each plot.

PROVENANCE EXPERIMENTS

By R. LINES

Lodgepole Pine (232.12)

DURING the year an intensive assessment programme was carried out in the lodgepole pine experiments on provenance. In addition to measurements of the height and girth, counts were made of the number of shoots still living which were produced during the last five years. It is already obvious from a cursory examination of the data that the typical coastal provenances have many more shoots than have the typical inland provenances. It is, in effect, an arithmetical expression of 'bushiness', a factor of silvicultural importance where vegetation suppression and resistance to exposure are required.

The Forest Service of the Irish Republic kindly sent us, early in 1954, seed collected from six stands of lodgepole pine in that country. Since some of these stands have shown excellent growth under somewhat severe conditions, where Scots pine failed to survive, it was thought their progeny might also do well in Scotland and we are greatly indebted for this gift. These stands are thought to be of the coastal provenance of lodgepole pine, of which there are few crops old enough for seed collection in Britain.

This seed was therefore sown in a replicated nursery experiment, along with seed from the Lower Fraser River, one of the usual seed collection areas in British Columbia. At the end of the first year in the nursery there was little difference in height between any of the lots, the Canadian seedlings being near the mean of all lots.

Sitka Spruce

In October, 1954, an unusual type of discoloration was noticed in the Sitka spruce provenance experiment at Kielder Forest, Experiment No. 53 planted in 1950. The needles showed vivid yellow and purple discoloration of a type normally associated with nutrient deficiency, but not entirely typical. It was at first thought that the needle discoloration was due to frost because there had been a severe frost there on 27th and 28th September, when 10° of frost was recorded. On closer examination, however, it was seen that normal frost damage to the shoot tips was present on up to fifty per cent of the plants, but that unusual discoloration damage was confined to the older needles away from the shoot tips. Later, during the winter, the discoloured needles fell off.

The damage was assessed in November, 1954, and the results examined statistically. These show that the two provenances from Queen Charlotte Islands, B.C., and Harwood Forest, Northumberland (the latter originally from Queen Charlotte Islands seed), were significantly less affected by both frost and discoloration than the six other provenances from Washington, U.S.A. There was a positive correlation between frosting and discoloration. The worst provenance, from the Nemah River, Washington, had ninety-four per cent of the trees affected by discoloration, whereas the Harwood lot had only twenty-five per cent affected. The susceptibility of the more southern provenances of Sitka spruce to frost damage is well known, though the frosts that kill back the shoots are more often those of the late spring when growth is very active.

When the discoloured plants were examined for fungal pathogens, a heavy infestation of *Rhizosphaera kalkhoffii* was found, but this was thought to be secondary.

Douglas Fir

Experiment No. 1, planted in 1943 at Glentress Forest, Peebles, was assessed in 1954. In this, there are two provenances from the interior of British Columbia —Salmon Arm and Prince George, and three from Vancouver Island. There is a large morphological variation within the species in Douglas fir, but, in general, one expects to find that coastal origins are of the *viridis* or 'green' type, whereas those from the interior of British Columbia are of the intermediate *caesia* or 'grey' type. Various authors (e.g. Wood: *Studies of North-West American Forests* (F.C. Bulletin 25), and Galoux: *Les Principales Essences Forestières de l'Amérique Septentrionale Tempérée*) have pointed out that in any one region one tends to get an admixture of types. A colour assessment of the Glentress experiment, on a colour index basis, showed that though the Interior British Columbian origins were in fact of a paler green colour, the differences between provenances are not statistically significant. Even in the most strongly defined *caesia* type plots there are dark green individuals of the *viridis* type.

This variation tends to confuse provenance differences which might otherwise show an important result; thus, when the plots were scored for *Adelgid* infestation on a visual basis in 1951, the coastal origins proved to be very much the most heavily infested. However, some of the plots of the interior Salmon Arm origin were recorded as being fairly heavily infested. Both in 1951 and at the time of the 1954 assessment, the Prince George origin was remarkably free of infestation.

The various origins showed a differential susceptibility to the leaf cast disease *Rhabdocline pseudotsugae*, when this was first noticed on these trees in April, 1954. An assessment carried out by Mr. T. R. Peace in June, 1954, showed that the Interior British Columbian provenances were more heavily attacked than were the Vancouver Island ones. However, the disease was not confined to the *caesia* type, and all provenances suffered to some extent. The variation from tree to tree was much more striking than the variation between plots.

The 1954 height assessment showed that apart from the Prince George provenance, which was tallest, there was very little difference between any of the other provenances. None of the differences in height was statistically significant. It seems likely that the freedom from *Adelgid* attack of the Prince George provenance has contributed to its superior growth, while the growth of the heavily infested Vancouver Island provenances must have been reduced.

DERELICT WOODLAND INVESTIGATIONS

By A. D. MILLER

(25)

Work has proceeded on a number of different aspects of rehabilitation. The main job is still the establishment of a series of experiments dealing with the principal soil and cover types, to compare the costs incurred and the type of crop produced by a number of treatments involving different intensities of initial effort. Other work included some studies of a fundamental nature on drainage effects in a heavy clay soil, some further experience in the use and handling of very large transplants for forest planting, and the beginning of a large-scale costed experiment in the use of heavy machinery for scrub clearance.

Rhododendrons (25.441)

Two rhododendron sites were chosen for the costed experiments, one on relatively level Bagshot Sands at Moreton Heath, Wareham Forest, Dorset, and the other on a steep, broken, and rocky hillside at Penmaen Uchaf, Coed y Brenin Forest, Merioneth. (See Photos 1 and 2.) Three treatments were laid down on each site:—

(*a*) All growth clear-cut and burned, followed by full planting at five feet by five feet.

(*b*) Strips twelve feet wide were cut through the standing rhododendron, leaving ten feet of untouched growth between adjacent strips. Three rows of trees were planted along each cut strip, spaced at five feet in the rows.

(*c*) Strips six feet wide were cut, leaving ten feet untouched between strips, and a single row of very large plants about three to five feet high was planted along each strip; in this treatment the trees were spaced at ten feet apart in the rows.

Before cutting began, the rhododendron growth was classified into two types at Moreton and three types at Penmaen Uchaf, in terms of its height and density of stocking, and adequate replications of each treatment were obtained within each type.

Douglas fir and *Abies grandis* were planted at Penmaen Uchaf, and *Tsuga heterophylla* at Moreton, species which form a dense canopy and cast a very heavy shade being chosen, so that eventually all rhododendron growth still present should be quite suppressed.

Two general points emerged from the initial stages of this work:—

(1) That the proper use of strips gives a considerable economy in the costs of preparing the ground for planting, yet still gives promise of a fully stocked final crop and complete eradication of the rhododendron. It had been expected that the narrower the cut strip in relation to the width of the uncut hedges, the greater would be the saving in initial costs. This seems to be true only up to a certain limit, for when cutting strips through very tall and dense rhododendron some fifteen to eighteen feet high, it proved so laborious to cut narrow strips only six feet wide that this method cost just as much as the twelve feet wide strips. However where the growth was only about ten feet high the narrower strips showed an important saving compared with the wider strips, which were in turn much cheaper than clear cutting. There is a strong suggestion here that there is no economic

advantage in having strips narrower than about half the height of the rhododendrons.

(2) That an important part of the economy of the strip system results from being able to push the cut material amongst the uncut hedges, so that little or no burning is necessary. It is generally possible to do this, but where the growth is so exceptionally dense that the cut material cannot be disposed of in this way but has to be burned, the costs rise sharply.

The Drainage of a Heavy Clay Soil (25:237.2)

The drainage experiment at an old woodland site on Oxford Clay, at Bernwood Forest, near Oxford, was mentioned in the 1954 *Research Report;* briefly it covers thirty-six acres from which all the old growth has been cut and burned, and combines factorially a comparison of different intensities of drainage, with a trial of species and mixtures. The assessments, to be made over a long period, will include measurements of drainage effects on soil moisture and aeration, profile development, depth of rooting, and tree growth. During this year the drains were dug and the planting has been almost completed. Initial measurements of the depth of the water table are reported on by Mr. J. M. B. Brown on p. 41 of this report.

Scrub Clearance Using Heavy Machinery (25:232—087.4)

The use of various types of machine for the large-scale clearance of derelict woodlands is increasing, and as it seemed likely that this trend will continue, it was decided to stage a large scale experiment to compare the efficiency, the costs involved, and certain long-term effects on the site and on the growth of the new crop, following the use of certain machines arbitrarily chosen as showing some promise. As a general point, a scrub-clearing machine may be designed either to uproot the whole of the scrub growth so that the ground is left relatively free from stumps and roots, or it may aim at cutting the growth at ground level leaving the root systems more or less intact and the soil scarcely disturbed. Considerations affecting the choice between using machines which will grub up the scrub growth, roots and all, and those which merely cut it off at ground level are:—

(*a*) Relative cost of the machine operations.
(*b*) Cost of disposing of the grubbed-up or cut-off material.
(*c*) Cost of controlling subsequent regrowth of woody species and other weeds.
(*d*) Effect on the soil, a wet clay, of using heavy machinery, and of disturbing the surface layers in the grubbing operations.
(*e*) Effect on the ease of salvaging any saleable produce.

In order to test the combined effect of all these matters, two types of machine which grubbed out the roots, and two types which cut at ground level, were chosen, and two sites totalling 180 acres were selected for experiment. During the year under review the plots were marked out, allowing six replications of five-acre units. In the hand cutting treatment which was added as a basis for comparison with the machines, work has been finished and the plots planted. Work with the first two machines, the Fleco Tree Cutter on a D4 tractor, and a standard Grubber Blade on a Fowler Challenger tractor, has started, and will be followed by the Foster 'Sabre' cutter and the 'Anchor chain' between two tractors.

Enrichment of a Devastated Woodland (25:235.6)

Redcap Copse in the Marelands section of Alice Holt Forest, was taken over as an example of a devastated wood from which all the valuable timber had been cut in a single operation. Originally this area had carried oak standards over mixed hazel and ash coppice, with birch scattered irregularly throughout; the coppice had not been cut for a long time so that, as the soil was an extremely fertile one on the junction of the Malmstone of the Upper Greensand and the Gault, the ash and birch poles had grown to thirty-five to forty feet high, and showed every promise of increasing in value if they were left to grow on. When the oak standards were cut about three years ago, gaps were left through which the unburned lop and top was scattered. These gaps are now dominated by coppice growth, and bramble growing through the old tops has added to the problem of restocking the area.

It was decided to accept all the potentially valuable poles in the ash/birch matrix, and to thin so as to encourage their development, and to secure adequate stocking over the whole area by planting trees three to five feet high at wide spacing in the existing gaps. The principal advantages of this type of transplant compared with the use of normal plants appeared to be:—

(1) The costs of preparing the ground for planting were much reduced. Had normal plants been used each gap would have had to be cleared and all the slash and the old tree tops burned; this would have been expensive. Using very large transplants, however, practically no ground preparation was necessary, the brambles and old tree tops were not disturbed, and coppice shoots were cut back only where they would have interfered with a plant. Also, owing to the wide spacing possible with very large plants, the costs of plants and planting were no higher than for normal transplants.

(2) In small and irregular gaps of this nature, the early weeding and tending of normal plants is troublesome and expensive, and if some groups are overlooked the plants suffer suppression by the vigorous weed growth. However, very large plants do not need any weeding, and come to no harm even if they are quite neglected for a few years, though eventually they will need to be relieved from the spreading side branches of the matrix and from coppice shoots within the gaps.

(3) Where rabbits are present the protection of small groups of normal transplants, scattered through a matrix which harbours the vermin, presents difficulties, but when very large transplants are used they can be protected efficiently and economically by using individual sleeves of roofing felt or similar material.

Four tree species were used, namely, oak, beech, Lawson's cypress, and a hybrid black poplar; the wood was divided into plots on the basis of the total area of gaps present, four replications being obtained for each species.

The early indications are that survival and establishment have been good.

An important side of this work is the costing; so all operations were timed, and records of the man-hours spent in each plot are being maintained.

SILVICULTURAL USES OF CHEMICALS FOR WOODY WEED CONTROL AND AS ANIMAL REPELLENTS

By G. D. HOLMES

Chemical Control of Woody Weeds (441:414)

ENCOURAGING results were obtained with basal bark sprays, using the *ethyl butyl* ester of 2, 4, 5-T in oils. Applications in the dormant season proved toxic to pole stage oak (chosen because of its relatively thick bark) and the work is being extended to cover a number of broadleaved species which may occur as weeds, both as maiden trees and as coppice.

For *Rhododendron ponticum*, ammonium sulphamate still appears the only satisfactory poison for application to freshly cut stumps, but further work on rates and formulations of 2, 4, 5-T is proceeding, and applications are being tried when the cut stumps are in foliage.

Calluna vulgaris (as reported by Holmes and Barnsley 1953*) has been satisfactorily controlled by the iso-butyl ester of 2, 4-D in oil at four to five lb. of the acid per acre in 160 gallons of oil. The aim of current investigations is to reduce the volume of fluid applied, which is at present inconveniently high.

Animal Repellents (451:414)

The studies described more fully in the last *Report on Forest Research* (G. D. Holmes 1954†) have continued: larger trees (*Populus gelrica* planted in December, 1953) being used in the current trials.

Bone oil, resin and 'CGA Repellent', applied to the lower part of the stems of the poplars, each gave a very high degree of protection against rabbits; by the spring of 1955 the trees so treated had been ignored by rabbits, whereas all untreated trees were seriously damaged. Possibly owing to the larger size of the plants (the previous work having been done on ordinary nursery stock of beech and ash), successful repellents did not on this occasion have any adverse effect on the trees.

The United States Wild Life Research Laboratory of Denver, Colorado, has kindly made available a number of promising substances which have already been given preliminary tests there; these will be tested under our conditions both for the protection of plants and for protection of seed directly sown in the forest. In connection with the latter, trials of bituminous preparations as protective covers, chiefly against mice, have been carried out on patch sowings in two forests. Early indications are that the larger pine seeds germinate surprisingly readily through a bituminous cover.

---

* G. D. Holmes and G. E. Barnsley, *Proceedings of British Weed Control Conference*, 1953. Page 289.

† G. D. Holmes, Experiments on Chemical Repellents for the Protection of Trees Against Rabbits. *Rep. For. Res.*, 1954. Page 147.

FOREST ECOLOGY

By J. M. B. BROWN

Water Relations of Clay Soils (114.463: 181.31)

A PRELIMINARY study has been made of the influence of artificial drainage on the winter water levels in a clay soil near Oxford. The site is in Bernwood Forest (Waterperry Wood), where an experiment comprising three drainage intensities and a trial of species has been laid down (see p. 38). The soil is derived from Oxford Clay and the profile shows marked drainage impedance; there is besides only a very slight fall, so that sub-surface lateral flow is extremely slow.

Several bore-holes were prepared, in one replication of each drainage treatment, in the early autumn of 1954, and the water levels in these were recorded at fortnightly intervals. The mean depth of water recorded in the undrained control was appreciably less than that in the intensively drained plot: levels in the plot of intermediate drainage intensity were intermediate but more variable, and not significantly different from those recorded for the extreme treatments. The data showed a close correspondence with recent rainfall: recovery after rain appeared to be more rapid in the intensively drained treatment, in which high levels were accordingly less often recorded in the bore-holes. In a prolonged dry period in early spring, differences between the treatments gradually disappeared.

The observations are being continued and, before next winter, the number of bore-holes will be increased, so that the records will have a sound statistical basis. Observations on the manner and rate of water movement and on the summer moisture content of the soil under the three treatments are also in view.

Natural Regeneration of Beech (231)

In Watlington Forest, Oxfordshire, observations were continued on the survival and growth of seedlings from the 1950 mast, under the three degrees of canopy opening provided in February, 1952. Mortality of the seedlings was rather greater in 1954 than in 1953, but there was an improvement in the height growth of the survivors, the mean height increment in the twelve observation quadrats being one-and-a-half inches in 1954 and one inch in 1953. It was observed in 1953 that mortality was greater in quadrats which showed a slow rate of height increment. A similar differential mortality occurs within individual plots, and there is thus an overall natural weeding-out of the less vigorous seedlings, which is to be observed even where mutual competition for light and root space has not begun to play any part. It must be stressed that the twelve observation quadrats, now increased to twenty-four by the addition of an equal number of trenched quadrats, are all situated outside the areas wherein brambles (*Rubus* spp.) and tufted hair grass (*Deschampsia caespitosa*) have increased very greatly since the regeneration fellings and smothered most of the beech seedlings.

With further elucidation of the significant factors in view, twelve trenched quadrats, situated so as to match the original twelve control quadrats, were set up in the winter of 1953-54. The assessment made in October, 1954, showed no significant difference in height (expressed as a function of initial height) between the seedlings in trenched and control quadrats. In the wet summer of 1954, it was not expected that trenching would cause an important difference in the supply of moisture to the seedlings. Early in 1954, also, an additional experiment was laid out, in which the effect on seedling development of improving the fertility of the site is being examined in a factorial experiment embracing the application of ground chalk (two-and-a-half pounds per square yard) and of a complete fertiliser (two-and-a-quarter ounces per square yard of potassic super-phosphate: 16 per cent K_2O and 16 per cent P_2O_5; and two ounces per square yard of 'Nitrochalk': 15.5 per cent N.). No assessment of results will be made until September, 1955.

In Slindon Park, Sussex, with the co-operation of the National Trust, an experiment was set up in February, 1954, in which, in a factorial layout, the influence on the germination and early growth of beech, of protection against rodents, of dressings of chalk to a base-deficient soil, and of surface cultivation, will be investigated in small replicated plots. The sowings made in March were largely destroyed by birds, of which jackdaws (residents in the wood) and wood pigeons appeared to be the most important. The quadrats were sown again with beech in 1955, after protection against birds had been provided for the plots protected against rodents.

The depredations of birds, which upset this experiment in 1954, were general in the Slindon Park beechwoods, and ruined the prospects for natural regeneration. The ground had been thoroughly scarified before seedfall and it was thought that the nuts might be conspicuous on the nearly bare floor. A second scarification was accordingly carried out soon after seedfall, but this was evidently far from effective in protecting the nuts. The brambles, which were almost completely removed in August, 1953, have reappeared locally, but most of the scarified ground is now colonised by a dense stand of millet grass (*Milium effusum*) interspersed with innumerable seedlings of foxglove (*Digitalis purpurea*). Some of the difficulties experienced at Slindon Park possibly arose through the opening up of the canopy too early, before seedlings were abundant on the ground.

Shade and Beech Growth (181.21)

A note on the experiment in Eartham Wood (Slindon Forest, Sussex), set up by the South-East Conservancy in 1948, was prepared for publication in the *Quarterly Journal of Forestry*; thanks are due to the local Officers for making available the annual assessments of height growth under the three degrees of overhead shelter. In February, 1955, measurements of diameter growth showed a difference (significant at the one per cent level) between the strongly shaded beeches and those in the other two treatments (light shade and no shade), between which there was no significant difference in diameter growth. It was concluded, therefore, that the degree of shelter maintained (corresponding to a transmission of about thirty per cent of full daylight midway in the course of the experiment, and of less than twenty per cent towards the end) caused no significant reduction in height increment, and fostered improved stem form in the beeches; but that it resulted in a considerable reduction in diameter increment.

The trees in this experiment were planted under birch and ash scrub in 1941, and the contrasted thinning treatments were applied in January, 1948.

Ecology of Corsican Pine (181)

Some progress has been made with an investigation of the growth of Corsican pine in Britain in relation to factors of climate and soil. Numerous records of growth collected during the past twenty years have been summarised on cards; these are being amplified and added to, with special reference to locality factors and to marginal sites, where this species shows indications of belying early promise. Although the custom has been to plant Corsican pine mainly on freely drained soils, in particular on the sterile sands and gravels of Eocene age in southern England, there is some evidence that it will give a good account of itself on retentive soils; the inference seems warranted that climatic factors are much more influential than soil factors in Britain. Highly calcareous soils are considered unsuitable; but the evidence about this is conflicting, and more investigation is called for.

As regards climate, it is clear that Corsican pine in the north of Britain is a suitable choice only for favourable sites. In the south, its remarkable tolerance of soil conditions make it a useful species on a wide range of sites, but neither the west coast climate, nor the climate of our hill lands, is fully suitable, even where establishment and early growth are satisfactory. It is not possible at the present stage to point to the probable limiting factors on these sites and the two cases may well call for different interpretations.

Survey of Checked Plantations in Mid-Wales (237)

A preliminary survey was carried out in the summer of 1954 of several hill sites in Montgomery and Cardigan, where the early growth of planted trees, chiefly Sitka and Norway spruce, has been disappointing. The sites are not peat covered nor excessively wet; nor is *Calluna*, though locally dominant, constantly present in the natural vegetation. Most of the ground is dominated by a grass-bilberry community, in which *Vaccinium myrtillus*, *Festuca ovina*, *Nardus stricta* and *Deschampsia flexuosa*, are all more or less abundant. Some of the least satisfactory areas are, nevertheless, dominated by western furze (*Ulex gallii*) and ericaceous plants.

A conspicuous feature of all this land, namely the steepness of the slope, has led to the suggestion that excessive site drainage may occasion periodic water deficiency in the soil in dry periods, notwithstanding the generally abundant rainfall. At the same time the soil is, on the evidence of the natural plant communities, markedly deficient in mineral nutrients; it is certain that both factors must be kept in view when an interpretation is sought for the disappointing growth of trees, and when remedial treatments are prescribed experimentally.

Although more or less considerably exposed to the prevalent westerly winds, the affected areas are not more exposed than some sites in the same neighbourhood, where growth has been a good deal better. Exposure to the wind may well account for the disappointing results with Norway spruce, and for the signs of blast on some plantations of lodgepole pine and Scots pine. But the poverty of the soil and the competition of the native vegetation appear to be generally involved.

POPLARS

By T. R. PEACE and J. JOBLING

(176.1) *Populus*

THE main emphasis has been on the establishment and maintenance of varietal trial plots and silvicultural experiments. Progress has been made in planting the populetum, while the testing of clones for resistance to bacterial canker has been continued on a wider scale.

Varietal Studies

Varietal Trial Plots (232.12)

One new area was started at Cannock Chase, Staffordshire, and planting was continued at Wynyard Forest in County Durham, Harling and Mundford at

Thetford Chase in Norfolk and at Quantock Forest in Somerset. A small number of plots were replanted at Yardley, Northamptonshire, where the original trees had failed, and a limited amount of beating-up was carried out in several of the other trial areas. There are now seventeen areas in England, four in Scotland and five in Wales.

Growth in many of the older plots is now quite vigorous, and full-scale assessments will be started in these during the coming season.

Varietal Collection

The collection contained 304 clones in December, 1954, compared with 246 in November, 1953. Although a number of clones have been discarded during the year, others have been imported for inclusion in the populetum, and several more are to be planted in trial plots when sufficient plants have been raised.

Populetum

This now contains 125 clones, of which 28 were planted during the year. Each clone is initially represented by three trees, of which only one will be allowed to grow on to a large size.

Silvicultural Experiments (232.4)

Eight experiments were planted, so that the total number now maintained and assessed is twenty-nine. Some of the older experiments have been very informative, notably on planting treatments and age and type of planting stock. A summary of the position of each project is given below.

Age and Type of Planting Stock

Investigations into the raising of plantable one-year rooted cuttings (C1 plus 0) have been continued. One-year stock of this kind, suitable for planting out, has been raised successfully at Kennington Nursery, Oxford, for five years; this, when transferred to the field, has a similar rate of survival, and increases in height at the same rate, as one-year rooted cuttings stumped and transplanted for one year (C1 plus S1), the normal age for planting.

Experiments comparing establishment of different ages of hybrid aspen, *Populus tremula* × *tremuloides*, have shown that by cutting back one-plus-one or one-plus-one-plus-one transplants to the root collar in the nursery, and allowing them to grow on for a further year, a type of plant is produced which gives a higher rate of survival and greater height growth than unstumped stock when planted out. As with the native aspen, *P. tremula*, a considerably straighter plant results.

Planting Treatments

No work on this subject has been started since 1953, but experiments maintained since 1951 have shown conclusively that a mulch applied to the plant at the time of planting, and renewed annually for four years, increases growth at a greater rate during this period than does any other treatment.

The fertiliser experiments have only been partially informative, but the results suggest that poplars benefit more by an application of nitrogen, in the form of ammonium sulphate, than by applying either potash or phosphate, or both.

Liming of Plantations

Of the four experiments planted (the fourth was laid down during the year at Harling, Norfolk), only the first, planted in 1952 in the New Forest on an acid site, has so far given precise information. Here, the reaction of poplars to lime is such that trees in limed soil are three times the height of trees in unlimed soil after only three seasons, and there is still no suggestion that their rate of growth is falling off.

Use of Explosives in Planting

During the winter, an experiment was started at Alice Holt, in which the growth of trees planted in normal pits is being compared with that of trees planted in holes prepared by explosive. Polar Ammon Gelignite was used, in quantities of 1.6, 4.0 and 5.6 oz., to blow out the holes; using the lowest quantity of explosive, the holes approximated in size to normal planting pits, but using the two larger quantities, the holes were often two feet deep, with a diameter of four feet. Several drawbacks were encountered during the blasting operations and at the time of planting, but it is felt that these can be overcome, and further work is being considered.

Handling of Plants

Four experiments have been planted, of which two were laid down this year at Alice Holt. Results so far have been negative, in that exposure of poplar roots for different periods of time, up to a maximum of three weeks, does not cause the plant to die after transference to the field, nor has height growth shown any relationship to the period of exposure.

Chemical Weed Control in Plantations

The only experiment on this subject, which was planted at Hockham, Norfolk, in 1954, is still too young to be informative. The effects of six herbicides, on the growth of poplar and the degree of weed extermination, are being compared with the known effects of grass and sawdust mulches. Only one herbicide, p-chlorophenol dimethylurea (C.M.U.) seriously damaged the poplars; after spraying in the spring after planting, at the rate of ten lb. per acre, nine out of ten trees were killed. C.M.U. also caused the greatest reduction in the ground vegetation.

Spacing in Plantations

An additional experiment (the third) was planted at Pentraeth, Anglesey. In this, five spacings are being compared, namely eight, fourteen, eighteen, twenty-six and thirty feet, whereas in the first two experiments only the first four spacings were included.

Use of a Forest Tree Species as an Understorey in Poplar Plantations

One experiment has been planted at Cannock Chase, Stafford, in which the growth of poplar having an understorey of western hemlock, *Tsuga heterophylla*, will be compared with that of pure poplar.

Effect of Wind on Poplars

Two experiments were planted, one at Pentraeth, Anglesey, and the other on a farm near Ely, Cambridgeshire, in which different varieties of poplar have been planted in a line running at right angles to the prevailing wind. It is hoped to find out which varieties are suitable for planting in exposed situations.

Nursery Experiments

The Raising of One-year Rooted Cuttings (232.32)

Reference has been made above to the work at Kennington nursery on the raising of plantable one-year stock. The project has now been extended to Fen Row nursery, Rendlesham, Suffolk, and to Alice Holt nursery, where cuttings have been inserted at fifteen by eighteen, eighteen by twenty-one and twenty-one by twenty-four inches. The plants raised in all three nurseries will be put out in a field experiment in 1956.

Manuring of Cutting Beds

Large scale experiments were laid down at Alice Holt nursery, Nagshead nursery, Forest of Dean, and Dean Barn nursery, Queen Elizabeth Forest. Hampshire, comparing the growth of cuttings in soil treated with compost, and those in soil which has received different combinations of a balanced potash and phosphate fertiliser, together with either ammonium sulphate or Nitrochalk.

Distribution of Cuttings (232.328)

During the year, 1,217 cuttings of a wide variety of clones have been sent to research workers in Canada, Germany, Holland, Hungary, Ireland, Pakistan, Poland and Switzerland, as well as to interested growers in this country. This number far exceeds the totals sent abroad in previous years.

Cuttings of the standard varieties have again been widely distributed to private estates, to the trade and to the Forestry Commission Conservancies. The total number disposed of was 32,125, compared with 39,400 for the previous year and 27,236 in 1953. It is interesting to note that the Forestry Commission requirements have steadily risen since cuttings were first available in 1949, whereas allocations to the trade and private estates have fluctuated markedly during the seven-year period. The following table gives the number of cuttings dispatched annually.

Annual sale of poplar cuttings

	1949	1950	1951	1952	1953	1954	1955
Forestry Commission ..	800	4,944	5,660	4,900	17,036	22,950	26,700
Trade and Private Estates	6,335	8,403	14,060	10,730	10,200	16,450	5,425

Bacterial Canker Investigations (443)

Inoculation with bacterial slime was again carried out at Mundford, Norfolk, on long cuttings of numerous clones, while the planting of rooted material between infected sucker growth of *Populus candicans* was continued at Parlington Park, Yorkshire, during the winter. A similar planting was made at Bretton Park, Yorkshire, where clones under trial have been planted between rows of diseased trees.

FOREST GENETICS

By J. D. MATTHEWS and A. F. MITCHELL

Survey of Seed Sources (232.311)

THE location of suitable seed sources for current and future planting programmes continued during the year. The survey of Scotland, covering all species in common use, was extended to Midlothian, East Lothian, Berwick, Roxburgh, Selkirk, Peebles, Dumfries, Kirkcudbright and parts of Ayrshire and Lanarkshire.

Two hundred and four woodlands and plantations were assessed and classified as suitable or unsuitable for seed collection. The total area of plus and normal seed sources in the counties mentioned above (i.e., in the South Conservancy of

Scotland) amounts to 857 acres. Scots pine, European larch, Japanese larch, Douglas fir and Norway spruce seed sources account for almost half, and oak, beech and sycamore for over one-third of the total area.

The survey of seed sources in Scotland, begun in 1951, is now practically complete, and a Register of Seed Sources has been compiled for each Conservancy. Six hundred and fifty-seven woodlands and plantations have been assessed and classified during the past four years, and the total area of plus and normal seed sources in Scotland amount to just over 4,400 acres. Scots pine seed sources account for fifty-five per cent, the larches for fifteen per cent and Douglas fir and Norway spruce seed sources together for nine per cent of the total area. Other coniferous trees such as *Tsuga heterophylla*, *Thuja plicata* and species of *Abies*, together make up five per cent of the total. Oak seed sources form twelve per cent and beech and other broadleaved species four per cent of the total area.

The Testing of Plus Seed Sources

Plants raised from seed collected from eleven seed sources of Scots pine from different parts of the East Conservancy of Scotland are being tested on three representative sites in North-east Scotland. The testing of plus and, to a lesser extent, of normal seed sources of Scots pine is to be extended. Plus seed sources which yield progeny which are vigorous and well-formed on the majority of the sites on which they are tested will eventually be registered as Elite or tested seed sources.

The Selection of Plus Trees for Breeding

The selection and propagation of outstanding phenotypes (plus trees) for use in producing new and improved varieties and hybrids of the major species was continued. The total number of plus trees of all species which have been marked and recorded is now 1,552.

The Testing of Plus Trees

Grafted plants and rooted cuttings are being raised for trials of the genotype (or tree displays) on representative forest sites in various parts of Britain. The establishment of the first large-scale tree display (containing forty-two clones of Scots pine, European larch and Douglas fir) was begun at Shouldham Forest, Norfolk. A site for a similar trial was selected in Northumberland.

The raising of plants for progeny trials continued. Seed from forty-seven plus trees of Scots pine, nine plus trees of larch and ten plus trees of Douglas fir was sown in spring, 1955.

Breeding

The establishment of seed orchards using clones of plus trees of Scots pine, the larches, Douglas fir, and beech continued. Six seed orchards, having a total area of eighteen acres, have been established; and work has begun on three more, totalling thirty-seven acres. Three new sites were found in Southern England.

Seed of the hybrid *Pinus banksiana* × *P. contorta* was sown at Alice Holt in the spring of 1955.

Vegetative Propagation

The final total of grafts made during the spring of 1954 was 10,360, and the total of successful grafts surviving to the spring of 1955 was 5,896, representing 255 parent trees. Three-quarters of these grafts were done at the propagation centres—Alice Holt (Hampshire), Grizedale Walled Garden (Lancashire), and the Bush Nursery (Midlothian). The remainder was done on seed orchard sites using rootstocks planted one or two years previously in the positions chosen for the successful grafts. This practice is being considerably extended whenever it is possible to obtain good scion material.

Further improvements were made to the glasshouses at Grizedale. The capacity of the range of lean-to glasshouses, which are used for spring grafting under glass, is now 3,000 potted plants. The greater part of this space is used for the propagation of old plus trees of Scots pine, which almost always produce poor scion material.

Propagation by cuttings continued. (Photo 5.) A new propagation frame with sub-irrigation and electrical soil warming was used for rooting cuttings of European, Japanese and hybrid larch. The results obtained were a great improvement on previous years, fifteen per cent of the cuttings inserted in June being rooted and ready for lining out in September. The principal factor limiting success has been attack by the fungus *Botrytis cinerea*. The work on the propagation of larch by summerwood cuttings is to be continued, and the effectiveness of some new fungicides in controlling *Botrytis* will be tested.

Summerwood cuttings taken from two Sitka spruce trees showing apparent resistance to the Green Spruce Aphis, *Neomyzaphis abietina*, and two individuals of *Thuja plicata* showing apparent resistance to the fungus *Keithia thujina*, were successfully rooted at Alice Holt and Bush Nursery, respectively.

Flowering and Fruit Production

Phenological observations were again made on individual trees and grafted plants growing in the neighbourhood of Alice Holt. An item of interest was the extreme susceptibility of the male flowers of *Sequoia sempervirens* to the low temperatures normally experienced in springtime.

Further details of progress during the year ended March, 1955, are now given by species:

Beech

Ten plus trees were selected in the fine beech stand at Slindon Park, Sussex. These were propagated by grafting during the spring of 1954 and the successful grafts were lined out for a further year in spring, 1955. These ten clones will be used to form a seed orchard for the production of the Slindon origin of beech.

Some four-year-old beech grafts flowered in April, 1954, at Alice Holt. The flowers produced were almost all female, and pollination was done with pollen collected from some mature beeches. The fertile nuts produced were sown in November, 1954, and some strong seedlings are now developing. The clone formed from Tree 33 in Cirencester Park, Gloucestershire, flowered best, four out of eight grafts producing from two to nine female flowers. Each individual graft of this clone differed in vigour of growth, in the production of normal and lammas shoot growth, and in flower production. Vigorous grafts which produced a moderate amount of woody growth in 1953 flowered in 1954. Vigorous grafts which produced a considerable amount of woody growth in 1953, and less vigorous grafts which produced very little woody growth, did not flower in 1954. These and other observations have confirmed that choice of rootstock and the production of clonal rootstocks are two important lines to follow in establishing seed orchards of beech and other tree species.

European Larch

Two hundred and seventy-one plus trees have been selected, forty having been found in the South Conservancy of Scotland during the past summer. Eighty plus trees were propagated during the spring of 1955, bringing the total number of clones formed to almost two hundred. Representative grafts from each plus tree are to be placed in two collections (or 'tree banks'), one in England and the other in Scotland. The grafted trees in these 'tree banks' will be used as sources of scion material, and comparative observations of flowering times and breeding behaviour will also be possible. A total of about 750 clones of various origins will eventually be included in these 'tree banks'.

Intra- and inter-specific hybridisation was continued on a small scale during the spring of 1955. The flowering of larch has been poor this spring.

Most of the grafting of the larches is done on the open nursery and on seed orchard sites; 2,300 grafts of European larch were made during March, 1955.

Japanese Larch

An intensive search for plus trees of Japanese larch continues. Fourteen plus trees were selected in the South Conservancy of Scotland, bringing the total so far to seventy. Scions were collected from twenty-two plus trees during the spring of 1955.

Scots Pine

Eight fine stands of Scots pine were noted during the survey of seed sources on the Charterhall and Mellerstain Estates (Berwickshire), on the Eildon, Hartrigge, Minto and Wells Estates (Roxburghshire), at Rachan House (Peeblesshire) and on the Shambellie Estate (Kirkcudbrightshire). All these stands have been classified as plus, all are over 130 years of age, and some at least are likely to be of native Scottish origin. Plus trees have been selected in each stand and propagated by grafting. Seed orchards for the production of seed of these origins will be established as soon as possible.

STUDIES OF GROWTH AND YIELD

By Dr. F. C. HUMMEL

Sample Plots (56)

A SUMMARY of the numbers of permanent sample plots established, re-measured and abandoned during the year is given in Table 5.

Table 5

PERMANENT SAMPLE PLOTS

	England	Scotland	Wales	Totals
Plots in being, 1st April, 1954	293	215	87	595
Plots established 1st April, '54 to 31st March, '55	36	5	24	65
Plots written off (blown, felled, etc.)	3	1	3	7
Plots previously written off—reclaimed	2	2	—	4
Plots in being 31st March, 1955	328	221	108	657
Plots re-measured 1st April, '54 to 31st March, '55	56	85	33	174

Of the sixty-five new plots, thirty-four were established in spacing experiments, the object being to study how the effects of different thinning treatments on a forest crop are influenced by differences in the initial spacing of a plantation. Ten of the new plots were in plantations of promising, but not yet widely planted, coniferous species such as western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*) and the grand silver fir (*Abies grandis*). The eleven new hardwood plots include the first plots of ash, sycamore and birch in Scotland.

Gale damage was severe, mainly in south-west England and in south Wales: seven plots were destroyed and written off, while other plots in which damage was less severe were retained in order to study the effects on increment of different degrees of wind damage. For the same purpose two plots previously written off in Scotland were 'reclaimed'. The two 'reclaimed' plots in England had been abandoned on account of *Fomes* damage in 1945, but are now to be used to study the rate of growth of the surviving trees, which has been encouraging.

In addition to the establishment and re-measurement of permanent sample plots, ninety-five temporary plots were measured in coniferous species for which no yield tables have as yet been prepared. The object was to supplement the data from the permanent sample plots in these species, in order to get some provisional indication of their rates of growth. Table 6 gives particulars of these plots by species.

Table 6

SAMPLE PLOTS OF MINOR CONIFERS

Species	England		Wales		Scotland		Great Britain		
	Temp. Sample Plots	Perm. Sample Plots	Temp. Sample Plots	Perm. Sample Plots	Temp. Sample Plots	Perm. Sample Plots	Temp. Sample Plots	Perm. Sample Plots	Total
Hybrid larch ...	—	3	—	1	6	13	6	17	23
Lodgepole pine	8	1	5	—	8	5	21	6	27
Grand silver fir	3	2	6	1	8	8	17	11	28
Noble fir ...	—	—	2	1	15	3	17	4	21
Western hemlock	3	6	4	2	4	6	11	14	25
Western red cedar	7	5	2	2	5	3	14	10	24
Lawson's cypress	4	—	2	1	3	1	9	2	11
Total	25	17	21	8	49	39	95	64	159
Grand Total...	42		29		88		159		159

Past increment in these temporary plots was determined by stem analyses and increment borings, which were analysed by a method specially evolved for the purpose, as the existing methods were found to give unsatisfactory estimates of volume increment in fast-growing, even-aged plots.

A thorough review of sample plot methods was undertaken in order to reduce the work without sacrificing useful information. Considerable modifications to existing practice and accepted ideas have resulted, and a Code incorporating the new procedure has been drafted. One item of the new procedure is the use of the new Barr and Stroud Dendrometer, based on a rangefinder principle, as a means of measuring standing sample trees. (See page 127.)

Statistics

The statistician, in addition to giving advice on the design of analysis of experiments to all sections of the Research Branch, and to carrying out much of the computational work involved, undertook a special study of experimental designs suitable for work studies and trials of tools, and of the use of sequential sampling schemes in forestry. He submitted a short paper on sequential sampling to the Fourth World Forestry Congress at Dehra Dun, and he has nearly completed the draft of a book on 'The Application of Statistical Methods to Forest Research'; this book is based on the work of the Forestry Commission Research Branch in recent years.

Census

During the year the counties of Ross and Cromarty, Flint, and Berkshire were completed, and work was started in the North Riding of Yorkshire. Reports on the counties of Angus, Kincardine, and Ross and Cromarty have been drafted. Census procedure has been simplified with a view to speeding up the work.

Forest Management (61)

A considerable proportion of the section's work was devoted to management problems. In connection with planning the establishment of wood-using industries in various parts of the country, long-term forecasts of production for various regions and various types of produce were required, and the Mensuration section assisted the Conservators concerned in preparing these forecasts. Field staff was again made available for the enumeration project in the Forest of Dean mentioned in the 1954 *Report*, and the Mensuration Officer (Scotland) assisted the Conservator for East Scotland in preparing a working plan for Tentsmuir Forest.

In addition to dealing with these *ad hoc* investigations, the whole question of management research was examined, and a start was made on tackling one problem of major importance in British forestry. This was to find a way of converting the very abnormal age-class distribution encountered in many of our forests into a more normal one, without either sacrificing much increment or causing major fluctuations in the annual yield. Although this investigation has not yet been carried far, it can already confidently be stated that the problem can be solved by combining heavy thinnings and slightly shortened rotations in the oldest age classes, with lighter thinnings and longer rotations in the youngest age classes. Conversion is further aided if, in applying these measures, skilful use is made of the variations in site quality which occur in every forest. Normality can thus be achieved without having to resort to expedients such as clear felling very young stands, or grouping several forests to form a single felling series.

Other Work

As Secretary of a Working Party appointed by the International Union of Forest Research Organisations, the Mensuration Officer took part in drafting a report giving recommendations on the standardisation of symbols in Forest Mensuration. This report is being circulated among members of the International Union of Forest Research Organisations and is to be submitted for discussion and approval to the next meeting of that organisation in Great Britain in 1956.

FOREST PATHOLOGY

By T. R. PEACE and J. S. MURRAY

(443)

A summary of work during the year on the many diseases under investigation is given below.

Group Dying of Sitka Spruce

A survey to find out whether the groups were associated with old fire sites was made at Glenfinart, in view of the propensity of the fungus *Rhizina inflata* to attack conifer roots on such sites. A high proportion of groups did contain old fires, but in view of the size of the groups in relation to the fires, the occurrences may well be fortuitous. Surveys of newly occurring groups were made in other forests, in several of which groups of Corsican pine, European larch and Scots pine were also found to be affected.

There is a superficial similarity between group dying and patches of conifers known to have been killed by diffuse lightning discharges. It is considered that this similarity is worthy of further investigation.

Top Dying of Norway Spruce

Die-back of pole-sized Norway spruce has been found to follow the 1947 drought at Allerston, and has also been noted in areas of low rainfall on sites where soil conditions make drought a possibility. Die-back on this type of site has also occurred where Norway spruce is competing with other species such as ash, Douglas fir, Sitka spruce, etc. Similar symptoms have also been seen where the spruce has been exposed by thinning or removal of side shelter. In all cases the symptoms appear to be the same, and the trees have reached a competitive stage. It is considered that in all cases the needles have dried out either owing to a direct shortage of soil moisture, or because exposure of the crown has disturbed the root/crown water balance, thus causing physiological drought.

Miscellaneous Fungi on Spruce

Lophodermium macrosporum has been recorded in two places in Scotland associated with severe browning on Sitka spruce needles in the nursery. The fungus had not previously been recorded in Scotland.

Rhizosphaera kalkoffii occurred regularly on the needles of Norway spruce affected by 'Top-Dying' (see above), but is now regarded as a secondary parasite.

In the autumn of 1954 Sitka spruce were found in two areas with pronounced browning of the needles of the current year, and heavy infection with this fungus. These attacks still await explanation, but it may well be that *Rhizosphaera* is not the primary cause.

Die-back of Picea omorika

It seems very probable that this disease may be explainable on the same lines as 'Top Dying' of Norway spruce. The injury to the Serbian spruce at Bedgebury, where this trouble occurs, is near the exposed edge of the plantation. At any rate no recovery has yet resulted from manuring with lime and phosphate, an experiment based on the possibility that the trouble might be associated with deficiencies of these elements.

Resin Bleeding of Douglas fir

Thirteen plots, each containing about eighty trees, have been set up in different forests to study the course of the disease. Most of the occurrences are in the south, with the most northerly outbreak at Clipstone. Inoculation experiments have been carried out with *Pycnidiella resinae*, *Cephalosporium* sp. and *Myxosproium* sp., the fungi occurring most commonly on affected trees.

Rhabdocline pseudotsugae on Douglas fir

A moderately heavy attack of *Rhabdocline* developed in the spring on a Douglas fir provenance experiment in Glentress Forest. All the provenances, which included both coastal and inland sites, developed the disease. The differences between individual trees in any one provenance were much greater than the differences between individual provenances. A similar general attack was also reported from a more comprehensive provenance experiment at Highmeadow in the Forest of Dean. (See also the section on provenance, p. 36).

Hitherto Douglas fir of coastal origin has been regarded as virtually immune to this disease in Great Britain, although it was known to occur in coastal regions in America. It was thought that we might have only one strain of the fungus in Britain, that being one to which the coastal form of Douglas fir was highly resistant. In the past, whenever it has been possible to trace the seed origin of a Douglas fir stand infected by this fungus, it has turned out to have come either from the Rocky Mountains (so-called Colorado Douglas), or from the interior of British Columbia (so-called Intermediate Douglas).

It is not possible to attribute this sudden attack on Coastal Douglas to the exceptional weather of the summer of 1954, because in fact infection must have taken place in the early summer of 1953. It will now be necessary to re-evaluate *Rhabdocline* with particular reference to race relationships.

Die-back of Corsican Pine

It is now generally accepted that the underlying cause of this trouble is the planting of the species outside its proper climatic range. However, one outbreak was found during the year near Killin in Scotland in which *Brunchorstia destruens*, a fungus often found in association with this type of injury, and normally considered secondary, did seem to be playing a primary role. Dead trees, diseased trees, and perfectly healthy trees showing no signs of climatic unsuitability, were all found growing within a few hundred yards. The distribution of the affected trees strongly suggested a spreading pathogen, and *Brunchorstia* was abundantly present.

Defoliation of Scots Pine

An unusually large number of outbreaks of browning of pine foliage were reported, some of which were due to winter cold and dry winter winds. Later, others proved to be a series of local epidemics of the needle fungus *Lophodermium pinastri*. Here the humid summer of 1954 may well be responsible.

Melampsora pinitorqua

Little progress has been made in the co-operative project with the Ontario Forest Service to test the reactions of *Pinus resinosa* and *Populus grandidentata* to this rust fungus, which has different stages on aspen poplars and two-needled pines. Both the species under test have been successfully established in a naturally infected area in Willingham Forest. A start has been made in setting up a special test area at Alice Holt, where other species of pine and aspen can be tried. This test area, however, has not yet been infected successfully.

Die-back of Pines and Other Conifers on Calcareous Soils

Another case of this phenomenon has been reported from Friston Forest, involving Corsican pine. Preliminary investigation has failed to reveal any other possible cause of death. A more detailed investigation will be carried out later.

Keithia thujina on Thuja plicata

Efforts to keep isolated nurseries free from the disease, so that they could be used for raising healthy stock, have proved rather disappointing. During the year under review three more of the nurseries under test have become infected. In one case this was due to a mistaken importation of infected plants, but in the other two the disease reached the nurseries, despite the fact that no *Thuja* plants at all were allowed in from outside. Work is still in progress to try and find the source of infection.

The humid summer led to extremely severe attacks of the disease in some nurseries, and efforts are now being made to ensure that a large area of infected two-year seedlings will be available for spraying experiments in 1956. Since the isolated nursery policy appears to have failed, efforts to control the disease by spraying, unsuccessful in the past, must be resumed.

Meria laricis on Larch

Before the war, when European larch was raised in larger quantities than now, so that it often occupied the same part of the nursery year after year, and when nursery manuring was often neglected, so that plants normally remained two years in the seedbeds and often two years in the transplant lines, this disease was really serious in many nurseries, and a spraying programme was devised to bring it under control. It was always confined to European larch, only once was it recorded on supposed hybrid larch, and Japanese larch was thought to be immune.

Latterly, although it has occurred regularly on European larch, it has done relatively little damage, because larch were seldom two years in the same place in the nursery, so that the fungus could not carry over the winter so well on the fallen needles. In 1954, however, it appeared in two nurseries in south-east Scotland and in one in Cornwall on Japanese larch, and in one nursery in North Wales on supposed hybrid larch. In no case was the attack really severe, but the new position obviously requires further investigation. It is not enough to blame the wet summer, because in the past unsuccessful efforts were made to infect Japanese larch artificially under conditions known to be ideal for infection, but without success.

Cronartium ribicola on Pinus strobus

During the summer the isolated plots of the Weymouth pine, *Pinus strobus*, planted the previous winter, were surveyed so that the nearest currant bushes, and in particular the nearest bushes infected with the fungus, could be located. In most cases all the currants within a two-mile radius of the plots have been located. One more fully isolated plot was planted during the winter, and most of the remaining stock of *P. strobus* was then used to form a series of plots rather nearer to currants, the pine being planted in mixture with other species. These will be surveyed for currant locations in the same way. All the plots will be kept under observation to see if and when infection takes place.

Botrytis cinerea on young Conifers

Trials of various fungicides were made on beds of Sitka spruce, Douglas fir, *Sequoia sempervirens* and *Cupressus macrocarpa*, infected by spore inoculation followed by covering with hessian frames. Successive counts of diseased plants showed that one application of fungicide was insufficient to give adequate control of infection. The data, however, were sufficient to indicate those fungicides worth using in the following season for further trials.

A very severe attack of *Botrytis* on Sitka spruce seedlings in Devilla nursery, Fife, following autumn frost in 1954, and subsequent snow, underlines the obvious need for more work on this disease.

Decay and Death caused by *Fomes annosus*, with especial reference to Second Rotation Crops

Preliminary work has been started on a series of large-scale experiments on the behaviour of *Fomes annosus* in second rotation crops, especially in relation to treatments such as poisoning, girdling or stump removal of the previous crop. This project was originally put forward at a small international meeting on *Fomes* held under the chairmanship of Dr. van Vloten in Wageningen, Holland, in July, 1954, and was discussed by forest pathologists from eight countries. Mr. Day, Dr. Rishbeth and Mr. Peace represented Great Britain at this meeting. Most of the work done so far has consisted of preliminary survey of possible experimental areas.

It is hoped to broaden the basis of this project to include some other aspects of *Fomes*, in particular the possibility of preventing its entry into virgin stands, possibly by stump treatment after thinning, and its behaviour in dry sand pine areas. Dr. Rishbeth of the Botany School, Cambridge, is closely associated with the work in an advisory capacity.

Bark Disease of Beech

The primary object of this investigation was to determine whether the death of bark on older Beech was caused by *Cryptococcus fagi* attack, followed by *Nectria* infection, or whether it was associated with years of climatic stress. So far, from examination of the material collected and data from observation plots, it appears that the latter explanation is the more probable one in Britain. Damage has been found to originate, for example, after the severe winter of 1940 and the drought year of 1949. In contrast no rapid deterioration of trees has been seen in plots in stands infected with the aphid *Cryptococcus fagi*.

Nectria ditissima Cankers on Young Beech

As a result of a survey carried out at Westbury Forest, Hants, it appears that the disease incidence has reached a peak and is now declining. No association could be found with frost or drought, but in many causes the origin of the canker was found to be mechanical, such as insect damage, rubbing, and in a few cases honeysuckle damage. There is no doubt, however, that once infection has taken place, the fungus can spread without further aid.

Bacterial Canker of Poplar

Inoculations, using the very large collection of clones assembled for trial purposes, were continued. It is hoped, when the inoculations made in the spring of 1954 have been assessed in the summer of 1955, to have sufficient data available for a first publication. Generally, the results from year to year are showing remarkable consistency. Of particular interest is the wide range of resistance and susceptibility found within the species *Populus trichocarpa*.

Sooty Bark Disease of Sycamore

This disease, which caused some alarm from 1948-51, continues to subside. A short survey of the known infected areas disclosed that active lesions were getting very hard to find. No convincing explanation has yet been put forward to account for the steady disappearance of this disease.

Elm Disease

Grafting material of five more near-resistant clones was received from Dr. Heybroek at Baarn, Holland. About twenty successful grafts were made from the six similar clones sent the previous year. In the spring of 1955, thirty-eight grafts were made from the new material, and 174 from the six clones received in 1955. All these clones are ones which, on inoculation in Holland, have shown a high degree of resistance, but not sufficient to allow of their distribution to the nursery trade. The stocks being raised in Great Britain will be used for planting under conditions of high natural infection, which should give a clearer picture of their suitability for general use.

No survey of the disease was made in 1954, but casual observations indicated that the attack was generally a light one.

Wound Protectants

A second test experiment with bituminous paints was started on branchy beech in Queen Elizabeth Forest, Hampshire. Preliminary assessment of the first experiment showed that stubs died back regardless of the material used, and are unlikely, therefore, to give results of any value. All the wounds in the second experiment were made flush with the stem. Preliminary data on rates of healing have been collected, but not yet summarised.

Discussion

While 1954 was obviously a season favourable to fungal attack, it would still be true to say that no disease has yet appeared which might lead to the abandonment of any of the species normally important in British forestry. *Keithia thujina* certainly makes the raising of *Thuja*, except in nurseries still unaffected, a very uneconomic business. The appearance of *Rhabdocline pseudotsugae*, which is a defoliating fungus of great efficiency, on coastal Douglas fir is disquieting: though it would be more serious, if it were not for the big variations in attack from tree to tree, which suggest that in any attacked stand sufficient individuals should survive to form a crop. No further work has been done on the other needle-cast disease of Douglas fir, *Phaeocryptopus gäumannii.* Data now being worked up for publication, which were collected over a period of years from over 150 trees in Wales and the south-west of England, suggest that while there is a connection between intensity of attack by the fungus on the one hand, and needle discoloration and fall on the other, it is not a very direct one, and often defoliation is delayed so long that the tree is hardly worse off than it would be without the fungus. Since severe defoliation by this fungus is uncommon, it is unlikely to prove a major factor in deciding our policy with regard to Douglas fir.

The importance of climatic influences in Great Britain is clearly illustrated by two of the diseases discussed above, 'Top-Dying of Norway spruce' and 'Bark Disease of Beech'. A completely unseasonable frost, which affected East Anglia at the end of June, provided further opportunity for collecting data and taking photographs of the extension of one of our most destructive natural agencies into a period when tree growth is usually safe. The severity of damage to Scots pine, usually regarded as a spring-hardy tree, was rather surprising.

Several visits were paid to the areas affected by the Scottish gale of January, 1953. Decay has played a much smaller part than was expected. Most of the species, other than Scots pine, were still alive, by means of the roots still connected with the soil. They were, as a result, still sound. In a very few cases blue stain had started in pine, but no evidence of incipient decay was found, even in the autumn of 1954. A yellow staining in pine, which did not affect the mechanical strength of the wood but which was considered by some to be an early stage of decay, proved to be chemical in nature.

FOREST ENTOMOLOGY

By Dr. M. CROOKE

The Pine Looper Moth, Bupalus piniarius (453)

THE major part of the Section's work was devoted to studies upon, and the organisation and assessment of control operations against, the Pine Looper, *Bupalus piniarius* L. The pupal survey of the winter 1953-54 had clearly shown that there had been an upsurge in the population densities of this pest in many pine forests throughout Great Britain. In particular, the two forest areas of Cannock Chase (Staffordshire) and Culbin (Morayshire) harboured high populations, and in the former area severe damage had, during the summer of 1953, already been inflicted upon some portions of the crop. It was considered essential to put into operation insecticidal control measures in these two forests, and at Cannock Chase an area of approximately 2,500 acres was delineated for control, whilst at Culbin the area for control extended to approximately 3,500 acres.

Although in this country we have had no previous experience of such large-scale insecticidal applications to forest crops, there is an abundance of information from other countries such as Canada, the U.S.A., Germany and Sweden, to indicate the insecticides normally used, their dosage rates, and the preferred methods of application. On this basis of foreign experience, therefore, the decision was reached to apply DDT at the rate of one lb. per acre in three gallons of spray liquid from fixed-wing aircraft.

The date for commencement of the control operations had to be based on two, to some extent antagonistic, considerations, viz.:—(*a*) that at the time of commencement all eggs should have produced their larvae, and (*b*) that none of these larvae should be old enough to have caused any serious feeding damage before the control was applied. Since the Pine Looper has a protracted flight period (at Cannock Chase, for example, in 1954, adult emergences continued from 15th June until 7th August), it is obviously impracticable to meet these two conditions absolutely. However, by a combination of data gained by field trapping of emerging adults, and from egg-hatching counts made on sample shoots, the date for the commencement of the control operation at Cannock Chase was fixed for the 9th August, on which date it was estimated that just over eighty per cent of eggs had hatched. At Culbin, the starting date for application was dependent on the completion of operations at Cannock Chase.

At Cannock Chase the progress of the operation was seriously hampered by very adverse weather conditions, and heavy rain and high winds were experienced for most of the time spent there. In all, nineteen days were required at Cannock Chase to complete the application over the 2,500 acres, whereas at Culbin, where the weather conditions were much more favourable, the treatment of 3,500 acres took only six days. Initially, too, at Cannock Chase difficulty was experienced in providing adequate ground markers for the pilots to set their courses, and this led to some hold-ups in the progress of the operation. Eventually, a marking technique, using two tractors rigged with standing poles from which flags and balloons could be flown above the level of the canopy, was put into practice. One tractor marked each end of the aircraft's run, and moved forward fifty feet—the swathe width—between runs. At Cannock Chase, where the terrain is in parts steeply undulating, intermediate static flag markers, attached to the tops of trees, had also to be used in places. At Culbin, where the average crop height is lower than at Cannock Chase, and where the topography is flat, no difficulties in marking were encountered.

The assessments of the results of treatment were based on three methods:–

(*a*) By direct counting of larvae killed by treatment. For this purpose, in selected sample compartments, trays measuring nine by three feet were set out, and dead larvae collected from them. The first counts were made a few hours after treatment, and thereafter at daily intervals until no more larvae could be discovered on the trays. In the areas of most severe infestation at Cannock Chase, the highest mortality counts yielded over one thousand larvae per square yard; at both Cannock Chase and Culbin mortalities in less severely infested areas averaged up to 100 larvae per square yard. In all cases, these counts are underestimates of the true mortalities, since a proportion of the larvae which, after poisoning, descend on silken threads from the crowns, become entangled in twigs and fail to fall to the forest floor. This type of assessment, however, although demonstrating that the treatment is having some effect, cannot give any estimate of the percentage mortality being produced. Accordingly, a second assessment method was used in an attempt to obtain some information on percentage mortality.

(*b*) By pre- and post-treatment shoot sampling for eggs and larvae. This technique was found useful for estimating the rate of egg-hatching. Its main objective, however, was to enable comparisons of larval counts, before and after treatment, to be made. Statistical analysis of the data collected shows, unfortunately, that the samples were inadequate for the purpose of making any valid comparisons of this nature, and the indications are that for any future work of this kind the sample unit will have to be the tree crown, and not one or more selected shoots as was used in this instance.

(*c*) A final check on the efficiency or otherwise of the treatments could be gained from the pupal counts in the winter 1954–55, and the comparison of these figures with those obtained in the previous winter's survey (as reported in the 1954 *Research Report*). These pupal-counting data support the view that the treatments have been effective and, to generalise, it can be said that the overall result of the control operations has been to reduce the populations of Pine Looper in these two forest areas to a level approximating to what can be considered an endemic one for British conditions. At Cannock Chase most of the treated compartments yielded *nil* counts of pupae, and the highest compartment average recorded was 1.8 pupae per square yard. At Culbin, too, most of the treated compartments gave *zero* returns, but a proportion of them had counts ranging from 0.2 to 0.6 pupae per square yard, and the highest compartment average obtained was only 0.8 pupae per square yard. Thus, the control operations in both forests appear to have gained their objective, and have certainly prevented any further defoliation.

Rather unexpectedly, and in contradiction to usual experience on the Continent, many of the pines at Cannock Chase which had been severely defoliated in 1953, either failed to flush or flushed only very weakly in the 1954 growing season. Consequently, many of them became infested with the Pine Shoot Beetle, *Myelophilus piniperda* L., and this has necessitated the clear-felling of some acres in one compartment, and the making of some heavy thinnings throughout a number of compartments where defoliation had been most intense in 1953.

The 1954-55 pupal survey embraced all the forests mentioned in the previous year's report, and in addition included some private estates in Morayshire, and Pembrey Forest in South Wales. Generally, there has been a distinct recession in numbers of Pine Looper in forests in all parts of the country, and this population drop is attributable in the main to the inclement weather of 1954, which produced mortality at all stages of the life cycle from adult flight onwards. In areas where counts were fairly high in 1953-54, the decline in population has been sharp enough to remove some forest areas, particularly in north-east Scotland, from the 'semi-threatening' class they occupied previously. For example, Roseisle Forest, Morayshire, where the highest compartment average in 1953-54 was 14.4 pupae per square yard, has in 1954-55 a highest compartment mean of 3.0 pupae per square yard. In only one forest, Sherwood 4 (Clipstone) has there been no appreciable drop in population density. In this area, although there have been fluctuations in distribution, a fairly high population has been maintained. In fourteen compartments a decrease, and in nine compartments an increase, has been recorded, and the highest compartment mean is now twelve pupae per square yard, as compared with nine pupae per square yard in 1953–54.

Further studies are now in progress on Pine Looper, and particular attention is being turned towards the attempted construction of life tables for the species, in an effort to define the more important mortality factors. One interesting topic of study centres round the observation that apparently only four larval instars developed in Britain in 1954, as compared with the normal five recorded from other countries.

Insect Development in the Scottish Gale-damaged Woodlands

The first year's work on the insect problems raised by the gale of January, 1953, was reported on in full in the 1954 *Research Report*. In 1954, attention was still centred in the main upon the development of Pine Beetle, *Myelophilus piniperda* L., infestations and, to study this, the same sampling technique used in 1953 was again put into practice. The results obtained are again remarkably uniform in character, and clearly show how the situation changed in 1954. It will be remembered that in the previous season breeding on any significant scale had taken place only in broken stems or in felled timber. In 1954, on the other hand, as most of the blown pine commenced to die off even where it had been uprooted and not broken, colonisation became very much more general. With this increased scope for breeding, coupled with the fact that the population had increased considerably in 1953, all the devastated woodlands where pine still remained on the ground became heavily infested with Pine Beetle. To date, the full effect of this great increase in bark-beetle numbers had not been felt, although shoot-boring in standing trees is now obvious, and in two forests breeding has commenced on standing stems. In 1955, when most of the blown timber will have been extracted, it can be anticipated that both feeding and breeding damage to standing pine crops will become both obvious and severe.

With the exceptions of minor species, such as *Ips acuminatus* Gyll., *Pityogenes quadridens* Htg., and *P. bidentatus* Herbst. on pine, which were fairly numerous, most other tree species, coniferous and broadleaved alike, were remarkably free from bark-beetle attack, nor was there any serious or common timber degrade of pine or other species caused by insect wood-borers.

In October, 1954, a survey was made to determine the development of the Pine Weevil, *Hylobius abietis* L., in the gale-devastated woodlands. The progressive clearing operations have provided extensive breeding reservoirs, and pine weevils have, in 1954, maintained the number of entries per fresh stump on a similar level to that recorded in 1953, whilst a second invasion of older stumps, first occupied in 1953, has raised their population by some fifty per cent. Exhaustion of these stumps through drying out is fairly rapid, as is the weevil development in them, so that the main emergences of young weevils can be predicted for 1955 and to a lesser extent for 1956. Throughout the gale-damaged areas as a whole, the distribution of centres of serious infestation tends to be rather patchy and this, coupled with the fact that the breeding sites are rapidly becoming exhausted, indicates that pine weevil infestations will probably be less severe than was previously feared.

Studies on Coniferous Sawflies

Pressure of work in other directions precluded the annual larch sawfly survey being made and consequently there is no detailed information on population movements of these species. Reports from central Perthshire indicate, however, that the minor epidemics of *Anoplonyx destructor* Bens. persist, and that autumn browning of larch caused by this species has been fairly severe.

In the absence of material from the survey collections, laboratory studies on the sawflies associated with larch, spruce and pine crops were conducted with stocks reared at Alice Holt in previous seasons. Progress has been made in the accumulation of general biological data on all species being handled, whilst the most concrete advance was the final distinction between the 'blue-green' species on larch and the very closely related *Pristiphora wesmaeli* Tisch. on the same host species. Biological differences between the two have been known for some years now, but the very close similarities between the adults have hitherto prevented a systematic distinction being made between them. However, adequate features of differentiation have now been recognised, and this has resulted in another new species being added to the list of larch-feeding sawflies. It is known as *Pristiphora glauca* Bens.

Insecticidal Control of Pine Weevil

Further field experiments on the control of Pine Weevil, *Hylobius abietis*, damage, by means of insecticidal dust applications to newly planted conifer crops, were carried out in 1954. As in previous trials, spot treatments of one ounce per tree were applied, and the insecticides tested were (i) ten per cent crude BHC, (ii) five per cent Dieldrin, (iii) Cotton dust 3.5.0 (=three per cent BHC plus five per cent DDT), (iv) Cotton dust 3.10.0 (=three per cent BHC plus ten per cent DDT). All the insecticides tested significantly increased the percentage of unattacked trees, and significantly reduced the mean damage score per tree, but dieldrin was appreciably less effective than either of the cotton dusts or crude BHC. The treatments were applied in April and gave protection for the whole of the growing season. Since these preliminary results are encouraging, further trails are now in progress. These include not only dusting, but also spraying and the dipping of plants before planting out.

GREY SQUIRREL RESEARCH

By M. NIMMO

(451.2)

UNDER the general direction of the Commission's Committee on Grey Squirrels, of which Sir Richard Cotterell is the Chairman, and in co-operation with the Infestation Control Division of the Ministry of Agriculture, various studies have been conducted on the grey squirrel population.

There is a need for some objective means of expressing changes in numbers of squirrels on selected sample areas, from year to year, so as to evaluate methods of control and to measure the effects of crop failures, weather conditions and disease upon the squirrel population. An experiment was therefore designed to test the two recommended methods of assessing relative numbers of squirrels. In one, the *walking count*, the same observer makes repeated walks over the same path through a wood, counting the squirrels seen each time. In another, the *drey count*, the number of nesting dreys in a particular wood is counted.

Population Studies

In order to gain as accurate an idea as possible of the absolute number of squirrels on the study area, animals were trapped, marked and released; then at the end of the experiment a large proportion of the population was shot and the ratio of marked to unmarked animals so collected allowed a calculation of total numbers. This detailed population study was carried out at Adhurst St. Mary near Petersfield, Hants, and yielded much useful information.

On an area of forty-six acres, with thirty-one traps, 357 captures were made, of which 164 were of different animals and 193 were recaptures. It is interesting to note that some individual squirrels were taken as many as seven times in the traps.

At the end of the trapping experiment, 163 squirrels were shot, of which 103 proved to be marked ones, and forty-seven unmarked ones. From this data the 'Lincoln Index Method' gives a total population 'at risk' as 217.

The walking counts, carried out before trapping was started, did not prove satisfactory; and it was concluded that at this time of year (May) the method is unsuccessful within any reasonable expenditure of time.

Counting the number of nesting dreys and multiplying the result by two (on the assumption that each drey held a pair of adults) gave a heavy overestimate of the squirrel population; and it is suggested that drey counts should only be done if all nests have been destroyed during the previous year, and therefore only the winter nests remain to be counted. Further it is doubtful if this figure should be multiplied by two—a better minimum estimate seemed to result from reckoning on only one squirrel per nest.

A point of great importance brought out by this experiment was the large proportion of the squirrel population on a given area that may be taken by skilful trapping.

Comparison of Control Methods

A drey-poking experiment, in which the dreys are destroyed by the use of pointed aluminium rods, has been continued at Alice Holt Forest in Hampshire. Here two areas—Abbotts Wood and Goosegreen—are compared annually. On the first area, normal trapping and shooting are carried out throughout the year, while on the second area no trapping is done but, once a year (in March or April), there is a complete drey-poking clearance and all squirrels are shot.

The following statement gives details of this experiment:—

Abbotts Wood (182 acres):

Normal shooting and trapping

Year	*Area in acres*	*Dreys*	*Total squirrels shot or trapped*
1953	182	871	141
1954	182	599	53
1955	182	322	47

Goosegreen (154 acres):

Drey-poking

Year	*Area in acres*	*Dreys*	*Total squirrels shot*
1953	56	169	13 (only partial clearance this year)
1954	154	535	66
1955	154	99	3

The poor mast year in 1954 has shown a weakness in the design of this experiment, that was not realised before—namely that the Abbotts Wood area contains quite a lot of Scots and Corsican pine plantations, whereas the Goosegreen area is practically pure hardwood. Therefore when acorns are scarce the squirrels go over to the Abbotts Wood plantations in search of conifer seeds.

At Alice Holt also, another experiment is in progress, in the Straits portion, seeking information on the season and annual breeding rate and movements of grey squirrels in a wood where they are not killed by trapping or shooting.

Information from Questionnaires

During the period under review two questionnaires have been circulated. The first was very widely distributed to landowners and others, and asked for details of shooting, trapping and dreys. Some 4,000 copies were sent out, and up to the end of 1954 about 500 had been returned, yielding useful information on distribution, sex ratios, and opinions regarding the relative effects of different methods of control.

The second questionnaire went out to Commission forests only and sought information on the damage caused by squirrels. At forty-four forests grey squirrels were reported to be numerous, and at 156 forests they were described as scarce; at 260 forests no squirrels were observed.

Of the 156 forests where squirrels were scarce, no damage was noted in 103 cases. The following list shows the relative incidence of damage to various tree species.

Species	*Number of reported cases of damage*
Sycamore	40
Beech	39
Oak	14
Birch	8
Ash	7
Japanese Larch	5
Hornbeam	5
Norway Maple	4
Sweet Chestnut	3
Scots Pine	3
Norway Spruce	2

Other trees on which occasional damage was observed included: aspen, gean, poplar, hazel, and the lodgepole, Corsican, and mountain pines.

Distribution of Squirrels

It was found that the questionnaire forms could be used to give information about the distribution of the grey squirrel in England and Wales in 1954. A map marked with the National (ten km.) Grid was used, and thirty-four squares were found to include localities reporting the presence of grey squirrels, for the first time. In areas where the species had been established for some time, the plotting of records confirmed its continued presence in 215 squares. The most striking new additions to the distribution were in Cardiganshire, where the grey squirrel seems to have spread northwards along the coastal areas as far as Aberystwyth, occupying six new squares. There were also six new squares in Montgomeryshire, and eight new squares in or near Shropshire; Derby showed three new squares, Lancashire, Merioneth, Devon, and Staffordshire showed two each, and Sussex, Lincolnshire, and Leicestershire showed one each.

In addition to these projects, work continues on the trials of, and improvements to, various squirrel traps. The leaflet *Traps for Grey Squirrels* was revised, and has since been re-issued, to publicise these recent improvements. Lastly a special Grey Squirrel Exhibit has been displayed at the main Agricultural shows.

MACHINERY RESEARCH

By R. G. SHAW

(——087)

In every industry today increased productivity is the only answer to increased labour costs and forestry is no exception. Mechanisation must play a large part in any attempt to improve output per man-hour and its application to forestry is being studied with results that are now yielding a return. Investigation by the Machinery Research Branch is divided into two main channels:—

(*a*) The design and development of new machines intended primarily for forest operations.

(*b*) Investigation into new agricultural machinery coming on to the commercial market where it appears to have some feature that might be applied to forest operations either in standard form or with some modification.

Amongst recent developments under (*a*) may be mentioned the lengthened and widened County tractor on thirty-inch tracks (Photo 10), which was described in the 1954 *Report*. Whilst this machine is basically a Fordson the alterations to make it able to haul a plough on soft peat have been of a major nature. Since last year the pilot model has been ploughing peat in the Border area where it has shown a high standard of reliability for so specialised a machine. Amongst the reasons for using the basic Fordson engine and transmission unit were the availability of spare parts throughout the country and, equally important, the low cost of repairs. Both of these advantages have been amply demonstrated during the year. It is interesting to note that the usage factor, i.e. the proportion of time actually worked expressed as a proportion of the available working hours, was forty per cent compared with twenty-nine per cent for other machines on similar work in another part of the country; this difference is largely explained by the difference in time spent under repair.

Of the standard machines mentioned under (*b*) above, the principal trials during the year have covered:—

(1) One-man chain saws of which the Norwegian Jo Bu Junior has established itself as the best saw tested in the under-twenty-five pounds weight class.

(2) Winches, amongst which the Boughton is proving popular as a tractor-mounted winch. A prototype of a new, very light portable winch which is interchangeable with the chain and blade of the Danarm Fury power saw, has been tested with promising results. The production model will be available for test in the coming year.

(3) The Holland nursery transplanting machine, mentioned later.

(4) The Fleco Tree Cutter also mentioned later.

Nursery Operations

The large amount of labour employed in forest nurseries makes them an obvious subject for examination with a view to mechanisation.

Many of the machines now available to the horticultural industry are not applicable to forestry owing to the different row spacing employed. Most horticultural crops are planted in rows about fourteen inches apart but forest nurseries use a row spacing of eight or nine inches. Forest trees need little individual space at the nursery stage, and close spacing gives economies in land, cultivation, and fertilisers. The American Holland planting machine, mentioned last year, has done well; but it still has to be proved under a wider range of conditions, such as side slopes. A considerable proportion of the lining-out at Bramshill Nursery, Hampshire, this year has been done with this machine; but it is too early to say how the results will compare with the hand lining-out which was done with planting boards at the same time. Weeding, being one of the biggest labour-consuming operations, has now come under investigation, and a machine for cultivating between the transplant lines has reached the design stage. Preliminary trials will be undertaken during the summer of 1955. Experiments in root pruning have been taking place locally for some time, both in England and Scotland, and a sledge-type implement designed for this purpose is now in wide use. (See Photos 6, 11, and 12.)

Extraction of Forest Produce

Extraction was the earliest forestry operation to be mechanised to any extent and a great deal of machinery for this role is now commercially available. Most of it was designed for handling large-sized timber, but an increasing proportion of the timber felled in the United Kingdom takes the form of thinnings, which means small loads spread over a wide area. The value of thinnings, per unit of volume, is lower than that of bigger timber; hence extraction costs represent a larger proportion of the value of the delivered product than is the case with mature timber. It is not easy to extract timber from inaccessible sites at an economic price; and new development has taken place in recent years on light equipment designed to deal with what is a comparatively new situation. A light power-operated ropeway was produced largely on the lines of the heavier Wyssen (Swiss) equipment. Trials have shown that when thinning crops where the yield is below 400 hoppus feet per acre, it is difficult to utilise any of the known power-operated ropeways at an economic cost. A new, very light gravity ropeway of Canadian origin is now on trial, with promising results for short distance transport.

Thinning in inaccessible places revealed the need for a light power winch which could be carried by two men, but which would be able to give a 1,500 lb. pull. A winch was designed to meet these requirements last year, and more recently some improvements have been made, including the fitting of a centrifugal clutch. Several of these winches have now gone into normal service. A great deal of physical effort can be saved by using the smallest wire rope that will stand up to these light logging operations. Tests have shown that a great deal can be done with a pull of 1,500 lb., and for this a $\frac{5}{16}$ in. diameter rope with a breaking strain of over 6,000 lb. is adequate. Since much manhandling of these ropes is involved, it is interesting to note that 100 ft. of $\frac{5}{16}$ in. rope weigh 18 lb., compared with 43 lb. for a similar length of $\frac{1}{2}$ in. rope, which is still very generally used.

Investigation into light ground anchors and pulleys for use with this light logging equipment has also yielded useful results.

Clearance of Derelict Woodland

The shortage of suitable land for the establishment of forests has directed attention to the large areas (about 600,000 acres) covered by derelict woodland. Much land of this sort has already been cleared for agriculture and/or for forestry, but the costs of clearing and burning, excluding removal of large stumps, has usually been around £28 per acre; and often there is little or no return for any of the produce to offset this high cost. To recover land at an economic cost for tree planting there must be a big reduction on this price.

A large-scale trial is to take place in the coming year to show comparable costs on measured plots when using most of the known mechanical means of clearance, and also clearance by hand. Perhaps the most interesting machine, as it is new in this country, is the American Fleco Tree Cutter, which is a horizontal knife mounted on the front of a tractor. This implement will cut down trees with stem diameters up to six inches. Other machines in the trial will be the Foster Sabre (a rotary cutter) and the Grubber Blade (a bulldozer with tines on the bottom of the blade); the method of sweeping with an anchor chain between two tractors will also be tried. (See Photos 8 and 9.)

Drain Cleaning

A great mileage of open drains in young plantations is in urgent need of cleaning. So far no machine has been found to relieve the labour and expense of cleaning by hand. A number of machines are available which can do this type of work, but they are all tractor-mounted and, apart from rideside drains, there is great difficulty in reaching most of the forest drains in young plantations with a tractor. Various ideas for self-propelled machines have been considered, and some have reached the trial stage; but none of them has provided a satisfactory answer. A dragline bucket for use in conjunction with the portable winch mentioned earlier in this report, is being made, to carry the investigation a stage further.

UTILISATION DEVELOPMENT

By E. G. RICHARDS

Hardwood Pulping (861)

THIS research project forms part of a study into the economic disposal of hardwood timber from coppice, scrub and devastated woodlands, a matter which has continued to occupy the attention of the Advisory Committee on the Utilisation of Home Grown Timber since it was constituted in 1949. A measure of the problem, as it was revealed by the Census of Woodlands in 1947, is given by the total area of such woodlands, namely 941,658 acres. Of this, 120,206 acres carried simple coppice, 229,788 acres carried coppice-with-standards, and 475,958 carried broadleaved scrub, while 115,706 acres consisted of devastated broadleaved woodlands.

Studies made so far have included a detailed review, in co-operation with the Rural Industries Bureau, of the state of the rural industries using hazel and sweet chestnut, the two more important coppice species. Summaries of the results have been given in previous reports, and it will suffice to mention that out of 49,621 acres of sweet chestnut, 19,261 were reported as *unworked*, while out of 117,351 acres of hazel, 105,151 were said to be *unworked*. These figures do not take into account a small area which may be worked, by estate labour, etc., from time to time; but they do give a general picture of the requirements of underwood industries based on these two species. Publications on these subjects are in preparation.

For the other coppice species, accurate figures are not available; but it is known that little of the area covered by them is worked on a regular basis. Hence it can be said that about 300,000 acres of coppice and coppice-with-standards are virtually unused, and that about 592,000 acres of derelict and scrub hardwood are unproductive. In addition to this potential source of timber, there are available, every year, several million hoppus feet from the hardwood forests in the form of thinnings, and markets for these are often difficult to find.

The results of the investigations suggested that there was little likelihood of increasing the demand for these types of material in traditional markets; a search for new markets was therefore begun. Tests on the suitability of using hazel for pulp were described in the *Research Report* for 1953. Subsequently this work, and the fact that there were unused supplies of hardwood, came to the notice of two groups of paper manufacturers who were aware of studies in the United States on the possible use of mixed hardwoods for pulping. It was agreed that the disposal of the unused hardwoods might be of common interest to the growers and the paper manufacturers, and a survey was therefore made of the potential supply of broadleaved thinnings, scrub and coppice, from private and Commission woods within fifty, seventy-five, and 100 miles radius of different centres in Southern England and Wales. It became clear that the minimum requirement for one mill, namely 36,000 tons of hardwood pulpwood annually, could be met at any one of several centres; but, if more than one mill were to be set up, they would have to be widely spaced to avoid drawing competitively on the same sources of supplies.

Parallel with this investigation, which was based on figures extracted from the Census of Woodlands by the Mensuration Section, the firms concerned carried out a search for a possible mill site, and one was found in Monmouthshire, at the western end of the Severn Tunnel. Here the large daily water requirements of a pulp mill could be met from the water which has to be pumped from the springs which were struck during the building of the tunnel; moreover, the potential supplies within a 100-mile radius were amongst the highest found for any centre in the South of England and Wales.

Samples of pulpwood of oak, ash, beech, sycamore, birch, sweet chestnut, hazel and Norway spruce from the Forest of Dean were sent to the Forest Products Laboratory, Madison, U.S.A., where their suitability for pulping was examined in a series of tests carried out on behalf of the two groups of paper manufacturers. The results of these tests have indicated that all of the above species could produce a good quality bleached pulp. By the end of the year the firms concerned were able to open preliminary discussions, on a commercial basis, with prospective pulpwood suppliers, namely, private woodland owners, the home-grown timber trade, and the Forestry Commission.

Other work carried out in this connection included the determination of the moisture contents of different broadleaved trees when freshly felled, with the object of getting some indication of the oven-dry weight of timber likely to be obtained from a ton of freshly-felled material. A paper on the results is included in this *Report* (see p. 112). Work was also undertaken to determine the average solid volume of timber in a *cord*, which is the customary measure for stacked branchwood. The results, obtained in numerous measurements made at the Forest of Dean and Chiddingfold Forest in Surrey, are summarised on p. 6; it should be noted that they are expressed in hoppus feet; volumes in true cubic feet would be approximately 27 per cent greater. The *percentage* of solid timber in a cord is almost the same as the number of *hoppus* feet it contains.

AVERAGE SOLID VOLUMES OF STACKS OF TIMBER MEASURING ONE CORD (128 *TRUE CUBIC FEET OVERALL*)

		Hoppus feet	
Branchwood—	Oak:	47.5±5.0	(Forest of Dean)
	Beech:	56.1±3.8	(Forest of Dean)
Thinnings —	Oak:	58.2±2.7	(Forest of Dean)
	Mixed Hardwoods:	55.2±0.93	(Chiddingfold)

For the Forest of Dean cordwood, where there was a wide range of mid-girths for the individual pieces in the stack, there was a significant regression of volumes, in terms of solid contents, on the mean girth of the stack. For a mean girth of eleven inches the average volume (solid) per stack of 128 cubic feet (stacked measure) was 41.8 hoppus feet; and for a mean girth of seventeen inches the volume was 52.8 hoppus feet. This suggests that, the larger the individual pieces of timber, the greater is the total timber volume, and the less the airspace. The variations in the results shown in the list above probably reflect variations in the range of mean girths and straightness of pieces within the stacks.

Thinnings House (242— —83)

The two-roomed office designed by the Timber Development Association, and referred to in the 1954 *Report*, was erected at Santon Downham, Thetford Forest. This project is a contribution to the study of the use of small-sized timber from early coniferous thinnings. For this reason a system of construction was employed which could make use of boards of small dimensions. The method chosen used prefabricated panels for the external cladding. These panels were made of boards varying between one and three inches in width, which were cut from logs of lengths of either forty-three or seventy-four inches, taken from early thinnings; the top diameters of these logs ranged from four to eight inches.

If it is assumed that poles of three-and-three-quarter inches breast-height quarter girth will give butt logs of the lengths specified, an indication can be given from yield tables of the earliest ages at which plantations are likely to give thinnings suitable for conversion into the boards of the type used for the cladding. The figures cannot, of course, be precise, because yield tables only give the size of the average thinning and not the range of sizes encountered (see Table 7 on page 68).

QUALITY CLASSES AND AGES OF PLANTATIONS FOR PRODUCTION OF TREES HAVING AN AVERAGE BREAST-HEIGHT QUARTER-GIRTH OVER-BARK OF THREE-AND-THREE-QUARTER INCHES.

Table 7

Species	Age in Years				
	Quality Classes				
	I	II	III	IV	V
Scots pine	30	35	40	50	—
Corsican pine ...	24	26	30	36	—
Japanese larch ...	18	21	25	30	40
Sitka spruce ...	18	20	23	30	35
Norway spruce ...	25	30	35	45	—
Douglas fir ...	16	19	23	25	33

The cladding panels in the building at Santon Downham were made from either Scots pine, Corsican pine, Douglas fir, Sitka spruce, Norway spruce or Japanese larch. The positions occupied by panels of each species were recorded, to enable the behaviour of the various species to be observed under changing weather conditions. All panels were lined with waterproof building paper; some were given, in addition, a backing of sawdust cement or of square-edged slabwood. The load-bearing framework, made by the Forest Products Research Laboratory, was also cut from coniferous thinnings.

In one room a suspended softwood floor of tongued and grooved Sitka spruce thinnings has been laid, and in the other, solid oak flooring blocks have been bonded to a concrete base screed with a mastic. All the window frames and doors are in mature home-grown Scots pine.

Although the office was not ready for occupation by the end of the year, measurements of the movement of the cladding timbers due to shrinkage and swelling were made. So far movement has been negligible in all species.

Wood Wool Slab and Chipboard Industries (862)

Surveys of the wood wool slab and the chipboard industries were completed. In the manufacture of wood wool slabs, over a quarter of a million hoppus feet of round timber is used per annum by eight firms, but less than one-third is home-grown. Knot-free Norway spruce is preferred. Some of the concerns use imported wood wool instead of shredding their own timber.

Five companies engaged in the manufacture of chipboard were found to be using about 40,000 tons of industrial wood waste annually. The use of round-wood or forest thinnings was not encountered.

Extractives from Wood and Bark (866.4)

More determinations of the tannin contents of various woods and barks were made during the year by the British Leather Manufacturers' Research Association in their laboratory at Egham. The results are given in Table 8.

TANNIN CONTENT OF HOME-GROWN WOOD AND BARK

Table 8

Material	Tannin Content % of the dry wt.	Non* Tans % of the dry wt.	Red† Colour	Yellow† Colour
Sweet Chestnut Wood ... ... (ex Rural Industries Bureau)	4.3	2.0	5	16
Sweet Chestnut Wood ... (ex Alice Holt)	6.5	1.9	2	9
Sweet Chestnut Bark ... ... (ex Rural Industries Bureau)	11.5	11.9	6	24
Sweet Chestnut Bark ... (ex Alice Holt)	18.9	11.8	6	18
Pedunculate Oak Wood ... ... (ex Alice Holt)	1.0	2.3	19	Over 50
Pedunculate Oak Bark ... (ex Alice Holt)	12.6	6.9	6	31
Hazel Bark ... ... (ex Alice Holt)	6.3	6.4	9	29
Japanese Larch Bark ... (ex Alice Holt)	14.3	18.1	6	27
European Larch Bark ... (ex Alice Holt)	12.5	10.5	4.5	22

* Water soluble material other than tannin. † Units given by Lovibond colorimeter.

It was decided, on account of its greater potential availability, to concentrate on investigating the prospect of Sitka spruce bark being used by the tanning industry. Some sixteen samples of home-grown Sitka spruce bark from different parts of the tree, from trees of varying vigour, and from different localities, have so far been analysed. The results indicate that the tannin content expressed as a percentage of the oven-dry weight varies between 14.9 and 22.5, the other water solubles (non-tans) vary between 11.1 and 15.2 per cent, the red colour between 2.9 and 5.9 units and the yellow between 6.8 and 18.5 units.

Arrangements were made for the experimental tanning of two sheepskins with Sitka spruce bark from Gwydyr and Eggesford Forests. The trials were successful in producing the type of leather which is used for wallets and other light leather goods.

Home-Grown Timber in House Building (833)

Preliminary discussions concerning the role played by home-grown timber in the building of both traditional and 'all-timber' houses were held with the appropriate government departments, and with certain local authorities.

Home-Grown Timber in Materials Handling (834)

An investigation into the use of home-grown timber in the box, packing case, stillage and pallet manufacturing industries was started during the year. So far Wales, Monmouthshire, Leicestershire and parts of Scotland have been covered.

THE LIBRARY AND DOCUMENTATION CENTRE AT ALICE HOLT

By G. D. KITCHINGMAN

Library

THE number of books in the library on the 31st March, 1955, was 2,504, an increase of 169 during the year. About one-fifth of these books are on permanent loan to sectional libraries. Other loans of books numbered 688, while 205 were borrowed from outside libraries. Sixty-eight volumes of periodicals were bound, bringing the total to 1,071.

Information Files

This section of the library increases slowly but has now become a valuable collection of typescript reports, separates, and loose material generally.

Documentation

Progress in this work has improved. The number of cards in the indices is now about 63,000, equivalent to about 20,000 references. Many lists of references to literature on special subjects were supplied to enquirers.

Bibliography of British Forest Literature

Considerable progress is being made in this special task, and between nine and ten thousand title cards have been prepared, and many of them cross-referenced in the general indices.

A.S.L.I.B.

Close contact was maintained with the Association of Special Libraries and Information Bureaux, of which the Library is a member.

Photographic Collection

During the year the numbers of colour slides and monochrome prints increased from 1,996 to 2,606, and from 9,819 to 11,833 respectively—a total increase of 2,624. Some 5,700 reference cards were typed for the index to the collection.

Increased use is being made of the collection, slides loaned for lecture purposes numbering 5,081, as against 1,216 last year.

Library Quarterly

Four numbers were issued during the year. The four library records issued with it dealt with:

(1) Factors governing the induction and development of flower buds in forest trees.

(2) The woodlands of Kent and Sussex.

(3) The classification of literature on statistical methods applied to forestry.

(4) The British birches.

Part II. Research undertaken for the Forestry Commission by Workers attached to Universities and other Institutions

NUTRITION PROBLEMS IN FOREST NURSERIES

By BLANCHE BENZIAN
Rothamsted Experimental Station,
Harpenden, Herts.

Manuring (232.322)

In 1954 several series of experiments on Sitka spruce seedlings, in which rates of both phosphate and potassium in annual applications had been tested, were brought to a conclusion. The tests were carried out at Wareham, Dorset; Ringwood, Hants; and Bagley, Kennington Extension and Old Kennington Nurseries near Oxford. Although the experiments covered different types of soil, ranging from very acid to nearly neutral, the responses to phosphorus applied as superphosphate were surprisingly constant. Averaging all nurseries and seasons, the response to three grams phosphorus per square yard was very close to a height increase of 0.25 inch. Doubling the rate of application gave twice the height response, indicating that higher rates of phosphate application could have been tested with advantage. A new series of experiments with rates of application up to twelve grams per square yard was therefore started in 1955. Responses to potash were smaller and more variable.

During the cool wet season of 1954, colour symptoms connected with potassium and magnesium deficiency were very characteristically developed in Sitka spruce seedlings, as well as in transplants. This year, for the first time since tests on magnesium were started in 1951, several experiments showed significant height responses to magnesium applied as magnesium sulphate.

Formalin and Fumigants

Work has continued to determine the conditions under which such materials as formalin and chloropicrin can be used most effectively and safely. If these materials are applied very shortly before sowing they may cause some damage. Winter applications (December or January) of both formalin drench and chloropicrin have given consistently good results over several seasons, but soil treatments at that time of the year may often be inconvenient, and even impossible, owing to bad weather; it was therefore decided to test applications in midsummer (June), autumn (October/November), winter (December) and early spring (February). Formalin was applied as a drench, containing either 167 or 333 ml. of formaldehyde, and chloropicrin injected at rates of 24 and 48 ml. per square yard. The results, averaging rates of application, are given in Table 9.

EFFECT OF FORMALIN AND CHLOROPICRIN SOIL TREATMENTS ON THE GROWTH OF ONE-YEAR SEEDLINGS OF SITKA SPRUCE, 1954

Table 9

	Mean height, inches		
	Kennington K 64	Ampthill Am 34	Ringwood R 64
Untreated	1.7	2.1	1.5
Formalin			
June	2.0	2.3	2.0
November...	3.1	2.9	2.4
December...	3.0	3.3	2.5
February	2.7	3.3	2.4
Chloropicrin			
June	2.4	2.7	2.4
November... ...	2.8	2.7	2.3
December... ...	2.9	2.8	2.3
February	2.7	3.1	2.2
	S.E. ± 0.11	± 0.08	± 0.08

As in previous years there were considerable responses to both materials. Except for the June application at Kennington, chloropicrin gave comparable height increases whatever time of the year it was applied. With formalin, the June applications were far less effective. The results for the autumn and winter applications were closely similar for both materials.

A new fumigant, CBP 55 (chlorobromopropene) was tested for the first time at Ampthill in 1954. It was injected and also applied as a drench. Both methods of application have given results closely comparable with those obtained from chloropicrin. The injection treatment was given at rates of 12 and 24 ml. per square yard of CBP 55 (approximately 55 per cent active ingredient). The drench consisting of the emulsible concentrate containing approximately 50 per cent by weight of CBP 55 was applied at 30 and 60 ml. per square yard in 4 litres of water. The results averaging rates of application are given in Table 10.

EFFECT OF TREATMENT OF SOIL WITH CBP 55 AND CHLOROPICRIN ON THE GROWTH OF ONE-YEAR SEEDLINGS OF SITKA SPRUCE, 1954

Table 10

	Ampthill (Expt. Am 47)	
	Mean height, inches	No. of plants per sq. yd.
Untreated	2.4	1,280
S.E.	±0.10	± 70.6
Applied in February:		
Chloropicrin injected	3.3	1,462
CBP 55 injected	3.0	1,516
CBP 55 drench	3.3	1,558
S.E.	±0.15	±99.8

PHOTO 1. Miller: Derelict Woodlands: Six-foot strip cut through dense rhododendron at Moreton Heath, Wareham Forest, Dorset; to be planted with western hemlock, *Tsuga heterophylla*.

PHOTO 2. Miller: Derelict Woodlands: Rhododendron clearance area at Penmaen Uchaf Coed y Brenin Forest, Dolgelley, North Wales. Foreground shows Treatment (*a*) complete clearance except for scattered birch, with full planting. Background shows Treatment (*c*) strips 6 feet wide cleared and planted, leaving 10-foot strips of dense rhododendron.

PHOTO 3. Zehetmayr and Farquhar: Disbudding Conifers: Typical Scots pine after disbudding for 6 seasons. Millbuie Forest, Ross-shire, Expt. 10/49, Tree No. 380.

PHOTO 4. Faulkner and Aldhous: Nursery Investigations: Applying chloropicrin to seedbeds at Alice Holt, using a Fumigun injector, and a grid to give spacings.

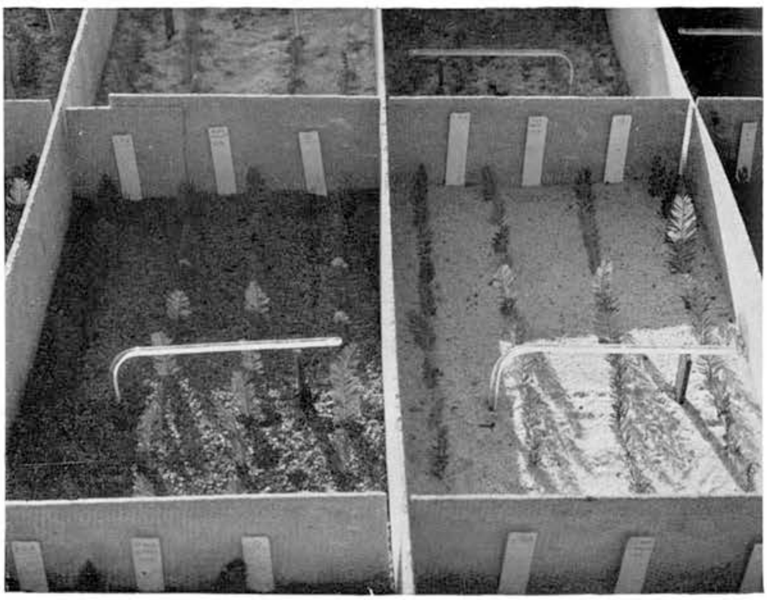


PHOTO 5. Matthews: Genetics: Striking cuttings of *Metasequoia glyptostroboides* in heated frames at Alice Holt, using various rooting media. Left, vermiculite; right, sand.

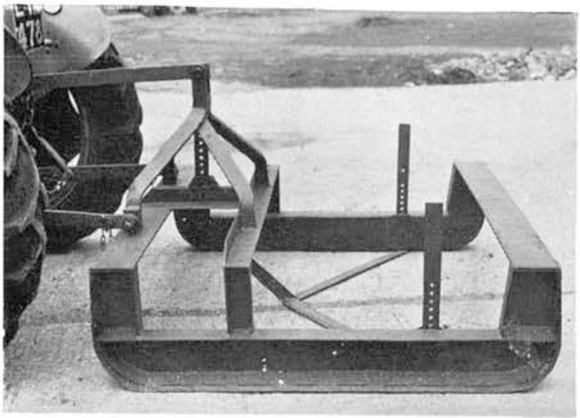


PHOTO 6. Shaw: Machinery Research: Tractor-drawn root-pruning sledge. In use, the V-shaped blade in the centre runs below soil level and prunes the roots of seedlings.

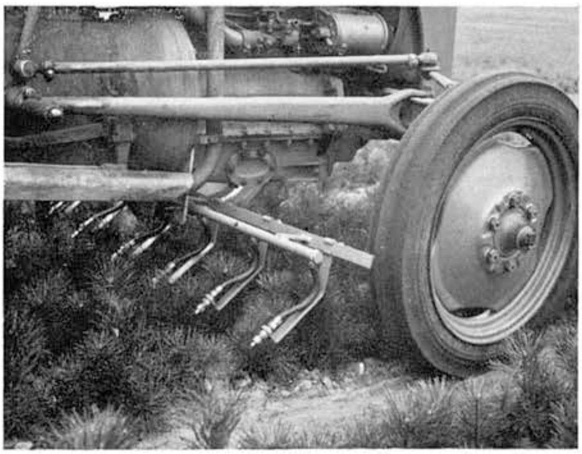


PHOTO 7. Faulkner and Aldhous: Nursery Investigations: Weed Control in Transplant Lines. Tractor-mounted spray boom for applying weedkiller to transplants of Scots pine.

PHOTO 8. Shaw: Machinery Research: The blade of the Fleco Tree Cutter.

PHOTO 9. Shaw: Machinery Research: Fleco Tree Cutter, mounted on a Caterpillar D4 Tractor, clearing scrub at Waterperry Wood, Bernwood Forest, Oxfordshire.

PHOTO 10. Shaw: Machinery Research: Experimental County Tractor with lengthened and widened tracks, drawing a Cuthbertson plough over boggy ground at Kielder Forest, Northumberland.

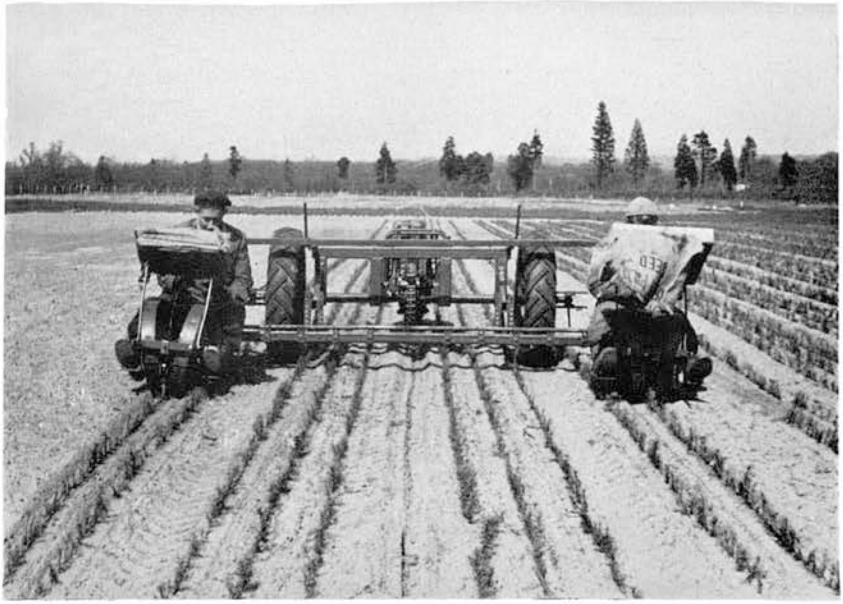


PHOTO 11. Shaw: Machinery Research: Rear view of the Holland Transplanter in operation at Elvetham Nursery, Bramshill Forest, Hampshire. The operators travel backwards, and feed the seedlings into the mechanism.

PHOTO 12. Shaw: Machinery Research: Front view of the Holland Transplanter, showing the automatic steering device running in a central groove.

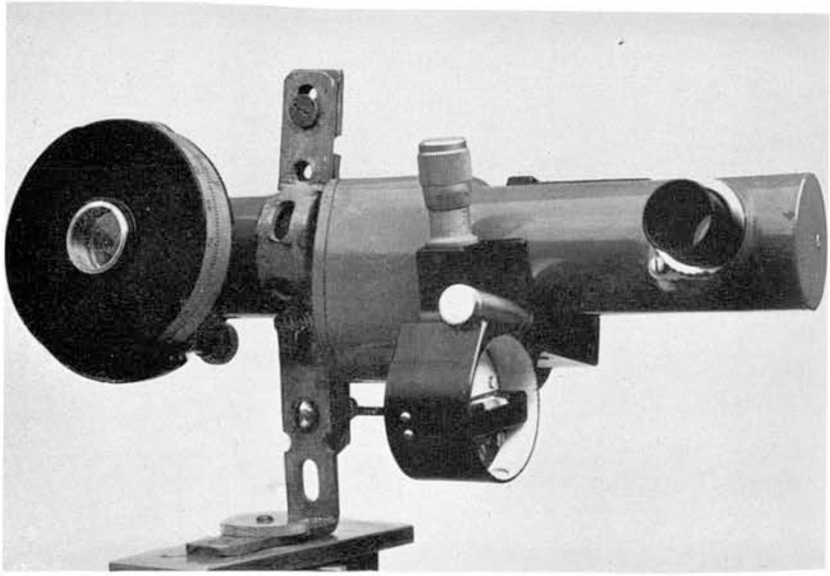


Photo 13. Jeffers: Barr & Stroud Dendrometer: Front view of the instrument.

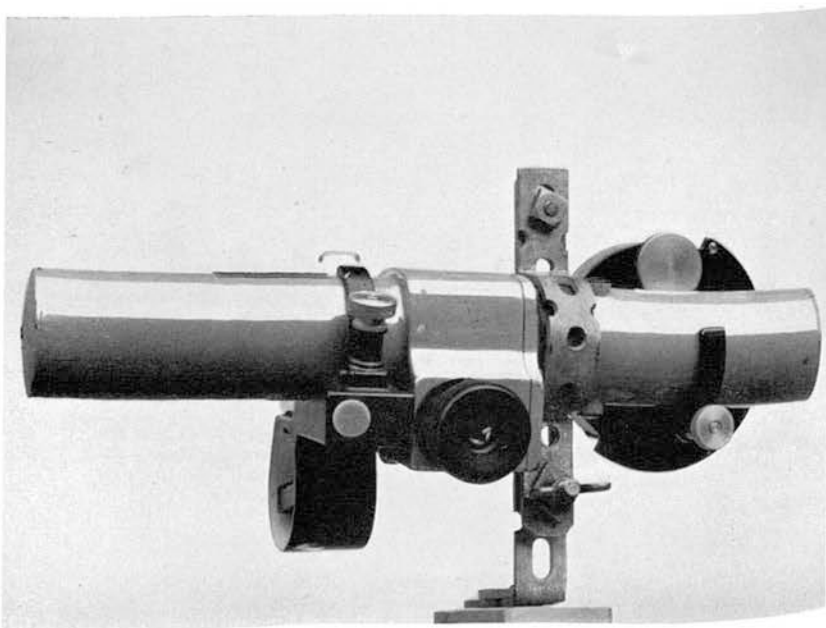


Photo 14. Jeffers: Barr & Stroud Dendrometer: Rear view of the instrument.

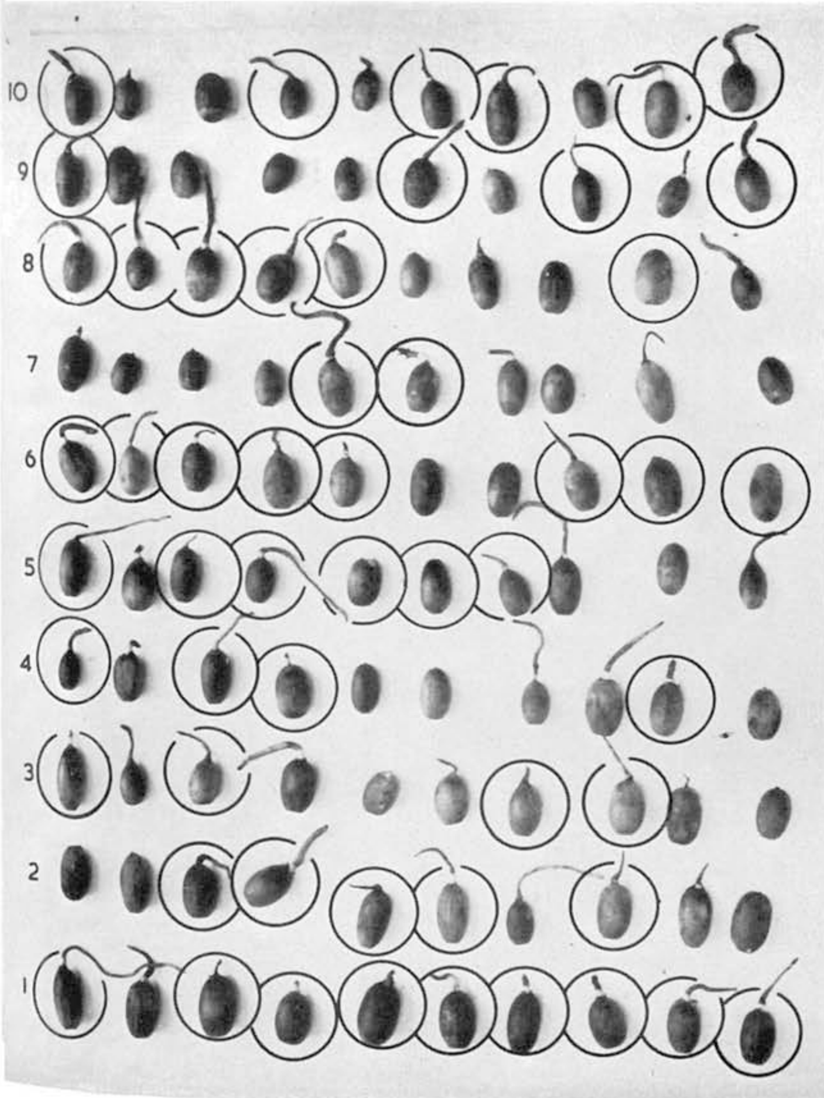


PHOTO 15. Acorns of *Quercus robur* L. after storage for 3½ years in air-dry peat at 36 degrees Fahrenheit. Ringed seeds produced seedlings in subsequent sowings.

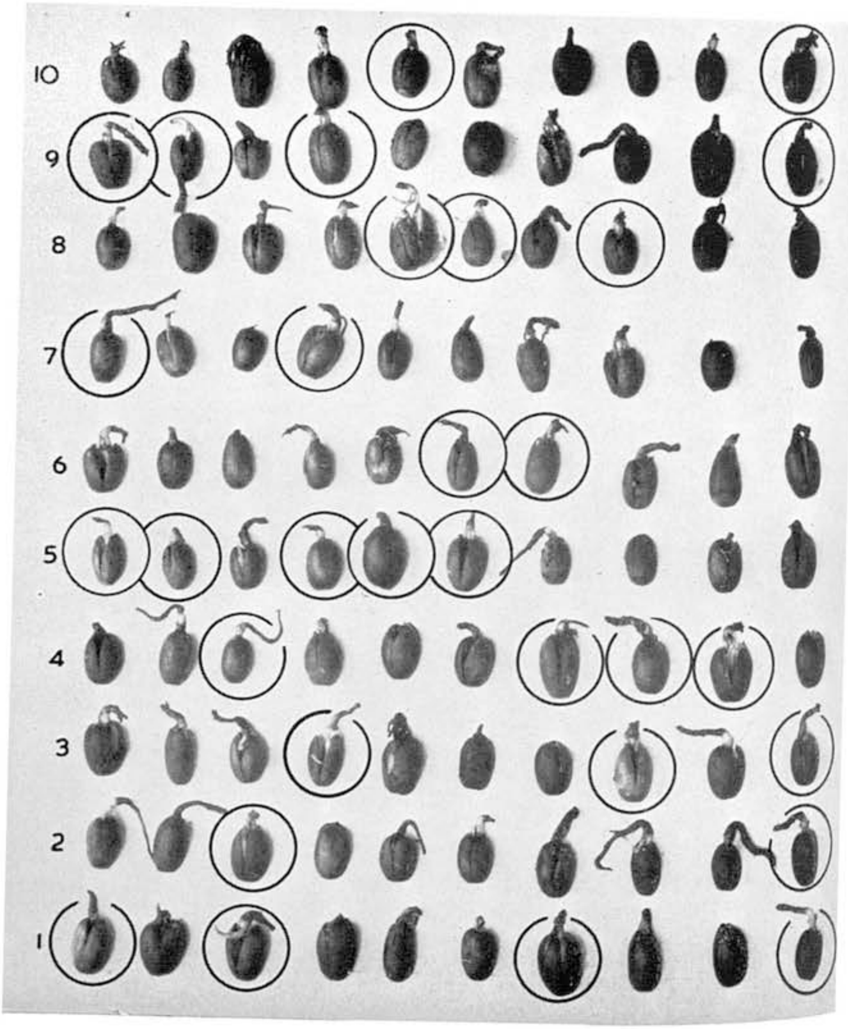


PHOTO 16. Acorns of *Quercus robur* L. after storage for $3\frac{1}{2}$ years in moist peat at 36 degrees Fahrenheit. Ringed seeds produced seedlings in subsequent sowings.

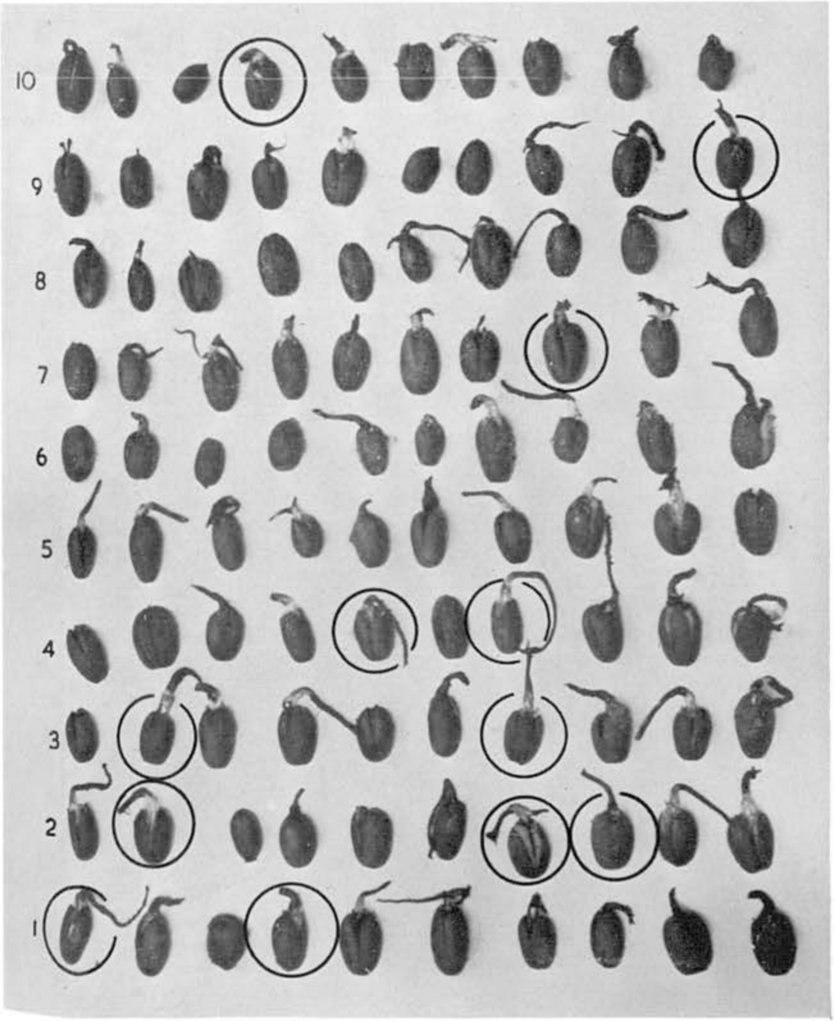


PHOTO 17. Acorns of *Quercus robur* L. after storage for 3½ years in moist sand at 36 degrees Fahrenheit. Ringed seeds produced seedlings in subsequent sowings.

PHOTO 18. Holmes: Chemical Bark Peeling: Easy removal of bark from a poisoned oak. Nagshead Enclosure, Forest of Dean, Gloucestershire.

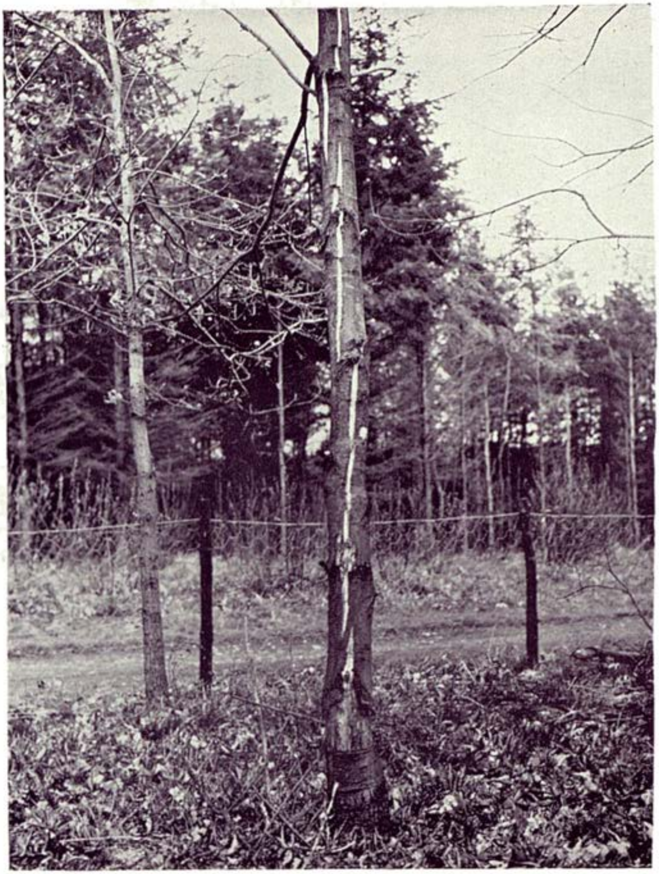


PHOTO 19. Holmes: Chemical Bark Peeling: Cracking and loosening of the bark of a poisoned chestnut. *Serridge Enclosure, Forest of Dean.*

EFFECTS OF TREE GROWTH ON SOIL PROFILE DEVELOPMENT

By Dr. T. W. WRIGHT,
The Macaulay Institute For Soil Research, Aberdeen

Corsican Pine Nutrition (181.343: 114.33)

LEAF analyses on material collected at monthly intervals from the thinning plots at Culbin Forest, and from a comparable area at Monaughty Forest, have been continued for a full year. The results are being assessed with the object of investigating a possible correlation between the abnormal fluctuations in foliage nutrient content already observed at Culbin, and the low levels of soil moisture existing in the dunes during spring and early summer. It appears that heavy thinning delays, for several weeks, the drying-out of the sand which occurs during the spring in the zone of greatest root development; and that during this period the foliage nutrient content of the trees in the heavily-thinned plots is greater than that of trees thinned to the lighter 'B' grade.

Measurements of height growth have been continued in the phosphate manuring plots laid out in young Corsican pine in April 1954, and the results of the periodic foliage analyses made throughout the year have been completed. No obvious response to the application of phosphate during the first year has been found; but there is a highly significant positive correlation between the nitrogen content of the needles at the beginning of the growing season, and the annual height growth of the trees. This agrees with the recent work of Leyton at Allerston and Clashindarroch Forests (*Rep. For. Res.* 1953, p. 105). Exceptionally vigorous trees with high nitrogen levels in the foliage were always associated with broom (*Sarothamnus scoparius* L.) which had colonised the area after thatching. The measurements are being continued.

Tree Growth on Deep Peat

An investigation has been started into the chemical and physical changes taking place in some of the deep peats of the north and west of Scotland as a result of afforestation, with the object of assessing the possible effect of these changes on the future growth of the trees. The sample plots and specimen trials at the Lon Mor, Inchnacardoch Forest, Inverness-shire, have been chosen as a suitable site for the preliminary work. Chemical analysis of a set of samples collected from the surface of unplanted peat, and from planted areas treated with ground mineral phosphate at various rates, has shown that it is possible to detect, by normal chemical means, the presence of phosphate applied up to thirty years ago. This analysis also suggests that the concentration of readily-soluble nutrients in the surface peat is lowest under trees showing the most vigorous growth.

Soil Studies in Thinning Plots

Work has been started on a study of possible soil changes taking place in some of the older replicated thinning plots established by the Forestry Commission. The Norway spruce sample plots at Bowmont Forest (owned by the Duke of Roxburgh), Kelso, and the Scots pine plots at Edensmuir Forest, Fife, have been chosen for a preliminary examination; surface samples have been taken from both areas, and the litter fall in the plots at Bowmont is being collected at monthly intervals.

STUDIES IN TREE NUTRITION AND IN ROOT DEVELOPMENT

By Dr. L. LEYTON
Imperial Forestry Institute, Oxford

Mineral Nutrition and the Growth of Forest Trees

Lawson's Cypress at Wykeham, Allerston Forest, Yorkshire (161.3: 181.34)

THE very pronounced response in growth following the application of a heather mulch has been found to be associated with a considerable increase in the nitrogen and phosphorus contents of the current foliage, as compared with untreated trees in the same plantation. Much of this improved growth, however, must be attributed primarily to better moisture conditions introduced by the mulch (cf. *Forestry*, Vol. XXVIII, p. 147, 1955).

Japanese Larch at Broxa, Langdale Forest, Yorkshire

Investigations on twenty-six trees in a six-year-old plantation showing considerable variation in height growth, have revealed significant linear correlations between tree height and the concentrations of nitrogen, phosphorus, potassium and ash in the current foliage (per cent dry weight). A multiple regression analysis of the data suggests that only the contributions made by nitrogen and potassium are significant, and a regression equation relating tree height to the concentration of these two nutrients in the needles has been calculated. The function $123.27\%\ N + 188.69\%\ K - 180.91$, provides an estimate of tree height with a standard error of ± 40.9 cm. and with a significant multiple correlation coefficient of 0.916. It is argued from these results that under the given conditions, the height growth of the trees is limited by deficiencies in both nitrogen and potassium. This conclusion is being tested by field trials with the appropriate fertilisers.

Scots Pine at Bramshill Forest, Hampshire

In collaboration with Mr. K. A. Armson, a detailed study has been made on the mineral nutrient status of trees of varying vigour in a nine-year-old plantation. Linear regressions have been calculated for tree height on the concentrations of various nutrients in needles sampled from different parts of the crown. Only nitrogen and potassium appear to make significant contributions to these regressions; the most significant relationships have been obtained with current needles sampled from the uppermost shoots and, in particular, from the leading shoot. It is concluded that, in the application of foliar analysis to the study of tree nutrition, strict attention must be paid to the location of foliage samples (cf. *Forest Science*, Vol. I (3) p. 210, 1955).

Complete records have been obtained for annual dry weight production in various parts of the crown, in terms of the nitrogen uptake by the trees and its distribution within the trees.

Environmental Factors and the Growth of Tree Roots

In collaboration with Mr. L. Z. Rousseau, apparatus has been constructed whereby the growth of seedling roots can be followed under controlled conditions of light, temperature and oxygen tension in the rooting medium. Experiments with seedlings of Norway spruce, with the roots at a temperature of 25°C., reveal a depressing effect of reduced oxygen tension on the rate of root growth, a 50 per cent reduction in growth being obtained at about 15 per cent dissolved oxygen. When given normal oxygen supplies, the normal rate of root growth was soon resumed, except in the case of an initial nitrogen treatment which adversely affected root development for a considerable period. At lower root temperatures (15°C.), reduced oxygen supplies had a very much smaller effect on root growth. With willow (*Salix atrocinerea*), root growth continued even when surrounded by pure nitrogen, though at a rate below that with normal aeration.

These investigations are being extended to a range of tree species.

FUNGAL DAMAGE TO ROOTS OF SEEDLINGS IN FOREST NURSERIES

By D. M. GRIFFIN

Botany School, University of Cambridge

(443.2)

THE main problem in many forest nurseries is to prevent the deterioration of soil conditions that results in the raising of progressively poorer seedlings as the age of the nursery increases. Recent work by the Forestry Commission and the Chemistry Department, Rothamsted Experimental Station, has shown that partial sterilisation of the soil results in improvement of the vigour of the seedlings grown therein and also reduces damping-off. The aims of the present work are to study fungi causing damping-off and root damage, and to investigate possible correlations between root damage and stunting.

Throughout the 1954 season, observations were made on plants growing in experimental plots at Ampthill Forest, Beds; Bagley Wood near Oxford; Ringwood Forest, Hants; Wareham, Dorset; and the three Kennington nurseries near Oxford. Considerable damping-off occurred at all nurseries except Wareham and Bagley Wood (pH *ca.* 4) and Kennington Three (newly established). The results of isolating fungi from diseased plants confirmed that *Pythium* spp. are the main pathogens. Experiments have shown that *Pythium ultimum* and *P. debaryanum* are highly pathogenic, whereas other *Pythium* species and *Fusarium oxysporum* have little or no pathogenicity.

In assessment of root damage, use has been made of the fact that these fungi typically kill root tips and immature sections of young roots, whilst older tissues that have escaped serious infection at an earlier stage are virtually immune. Thus, to obtain a root damage score for any plot to be sampled, twenty seedlings have been taken. Working back from the tip of the tap root, or in older plants any other representative point, root tips have been examined and the number killed, out of a sample of twenty tips per plant, recorded. A figure representing the average damage per plant in the plot has then been obtained. Tests have shown that such scores are consistent, both for different samples from the same plot and for different workers scoring the same sample.

Using this method of scoring, damage assessments were made on many thousands of seedlings throughout the growing period. These revealed that root damage was quite insufficient to be the main cause of stunting, although, in any given nursery, increasing root damage ran parallel with decreasing seedling size.

In particular, the difference in size between seedlings grown on unsterilised and on partially sterilised plots could not be attributed to the action of root-killing fungi. Partial sterilisation is known to affect the amount of readily available nitrogen in a soil, and especially the ammonium-nitrate balance; and it seems possible that the beneficial effect of partial sterilisation lies largely in this direction.

It is, however, necessary to emphasise that these conclusions concerning the relation between fungal root damage and the deterioration of seedling growth in ageing nurseries is based on only one season's results; it is essential that this finding should be confirmed by further extensive observations in future seasons. The possibility that the rhizosphere flora can produce a toxin causing stunting is being studied, as is the effect of physical soil conditions on root damage.

The inter-relationships between the prevalence of damping-off in soils of different acidity, and the pH optima of host and pathogen, are being investigated both in the field and by means of pot experiments. It is hoped that this will help to provide an explanation of the freedom from damping-off which most conifers enjoy in acid soils.

RESEARCHES IN SOIL MYCOLOGY

By Dr. I. LEVISOHN

Bedford College, London

Effects on Tree Seedlings Produced by Mycorrhizal Mycelia in the Absence of a Mycorrhizal Infection (181.351)

IN *Reports on Forest Research* for 1953 and 1954 accounts were given of experiments, the results of which demonstrated that certain mycorrhizal fungi, although not in partnership with the root, are capable of (1) stimulating shoot development, and (2) of influencing root morphology. During the past year these researches were continued and confirmed for species of pines and a number of other trees.

Effects on Shoot Development

Experiments designed to demonstrate the *rhizosphere effect* by *Boletus scaber* on shoot development, before actual mycorrhiza formation takes place, were carried out with pines, Norway spruce and birch. During the first year of growth in pot-cultures, no effect of inoculation was observed in the pine species tested. Norway spruce, however, showed, at the end of the first year, definite improvement in the colour of the foliage in the cultures which had received fungus inoculation. Birch, the main test plant in the last year's researches, reflected the rhizosphere activity of *B. scaber* in improvement of leaf size and colour, and slight increase in shoot development. The seedlings grown in heathland soil with the addition of the full amount of compost, supplied the following figures for average shoot length at the end of the first growing season:

(*a*) Control series, no inoculation with *B. scaber* (14 plants) 7.7 ins.

(*b*) Series inoculated with *B. scaber* (13 plants) 8.8 ins.

When a third of the usual amount of compost was given, the figures for average shoot length were:

(*a*) Control series, no inoculation with *B. scaber* (14 plants) 5.1 ins.

(*b*) Series inoculated with *B. scaber* (16 plants) 6.1 ins.

At the time of assessment, *B. scaber* had not formed an association with the seedlings.

The rhizosphere effect produced on an endotrophic plant by an ectotrophic mycelium was shown in pot-culture experiments using *Robinia pseudacacia* as a test plant and *B. scaber* as inoculum. Seedlings of *R. pseudacacia* which, like other leguminous plants, have been observed to form a 'double infection', i.e., endotrophic mycorrhizas in addition to bacterial nodules, were grown in sterilised heathland soil. The controls received an 'inoculum' of nutrient medium equal to that introduced with *B. scaber*. After the first season of growth, the average shoot lengths of the experimental seedlings were as follows:

(*a*) Control series, not inoculated with *B. scaber* (36 plants) 2.3 ins.

(*b*) Series inoculated with *B. scaber* (18 plants) 3.4 ins.

No trace of nodule or mycorrhizal infection was detected in either of the two series.

Effects on Root Morphology

Researches extending over a number of years have shown that, in pines, forking of the short roots can be induced by the activity of mycorrhizal mycelia without an infection being formed. The arrangement of the experiments was outlined in an earlier account (*Report on Forest Research*, 1952). It was observed that in the presence of mycorrhiza-formers in the experimental soils, forking of the roots which developed on the leaching water of these soils was a constant phenomenon. Although by naked-eye examination these root systems looked mycorrhizal, no fungal association had been formed.

When larch, Sitka and Norway spruce were grown under similar conditions, their root systems developing in the leaching water also demonstrated an influence on root morphology. While root systems from cultures in sterilised soil showed a conspicuous absence of short roots, those growing in the leaching water of the same soil, but inoculated with certain mycorrhiza-formers, developed a prolific supply of short roots. None of these roots exhibited mycorrhizal infection.

From observations carried out in inoculated sand cultures, it would appear that the inducing of forking in pine roots and of short-root formation in larch and spruces is due to growth substances similar to those observed by Slankis to form dichotomous branching in excised pine roots. Experiments are in progress to test the presence of such substances in leaching water from 'mycorrhizal soils' and in culture solutions in which the mycorrhizal mycelia have been grown.

In carrying out these experiments, *B. scaber* has proved a very suitable fungus. In contrast to the majority of mycorrhiza-formers, the mycelium of *B. scaber* was observed to grow vigorously on all the common culture media, on sterilised soils and certain litters, and also in liquid media.

It appears a difficult task to demonstrate the rhizosphere effect of mycorrhizal mycelia under field conditions. For most tree species difficulty arises from the fact that, in nature, mycorrhizas are formed rapidly and therefore uninfected root systems are encountered only rarely. *B. scaber*, however, seems relatively slow in producing mycorrhizal infection. In this, as in certain other respects, its soil activity is atypical among mycorrhiza-formers. *B. scaber*, which may be grouped among the transitional types of soil mycelia, on the boundary between obligate mycorrhiza-formers and litter-decomposers, was observed to delay or suppress the development of other mycorrhizal mycelia. In the field, as well as in pot-cultures, it was found to inhibit mycorrhiza formation (and probably general growth) of *Boletus bovinus* endemic in the experimental soil. A true antibiotic activity, however, has not been demonstrated. The inhibitory effect of

B. scaber on *B. bovinus* (and possibly other root mycelia) shows an analogy to the performance of certain strains of nodule-formers of clover. Some *Rhizobia* have been observed to dominate the rhizosphere, and to be responsible for the consistent failure of other strains of *Rhizobium* to produce appreciable nodulation. The phenomenon of interaction between various species of mycorrhiza-formers is at present under observation.

RELATIONSHIPS BETWEEN LARCH CANKER AND TRICHOSCYPHELLA WILLKOMMII

By Dr. J. G. MANNERS
Department of Botany, Southampton University

(443.3)

WORK has continued along three main lines, the study of the effects of the artificial inoculation of larch with *Trichoscyphella willkommii*, the production of artificial and controllable frost damage, and the taxonomy of *Trichoscyphella*.

The anatomical investigation of cankers produced on European larch by inoculation with *T. willkommii* in a frost-free locality, has been completed. The results show that all the histological abnormalities associated with natural cankers, with the exception of frost rings, can be produced in the absence of frost by the fungus. It is not, therefore, permissible to follow earlier workers in accepting the presence of these abnormalities as proof that frost is the causal agent of cankers.

The 1953 inoculation experiments, mentioned in previous *Reports*, have been kept under observation. Trees showing signs of infection in 1954 still had unhealed cankers in March, 1955, though the cankers were not very active. These experiments have confirmed that differences between strains of European larch exist, as regards susceptibility to *T. willkommii*, and further trials are planned.

Artificial cankers have been produced in potted trees frozen locally by means of a temperature-controlled cold air stream directed against the bark. Such cankers have been studied anatomically and, apart from the absence of fungus mycelium and the frequent presence of a frost ring, are very similar to those produced by inoculation with *T. willkommii* in the absence of frost. These results indicate that frost and fungus can each cause cankers, though in both cases the cankers tend to become inactive after a year or two. Further experiments were started in 1955 with a view to investigating the effects of treatment, on a single area of bark, with both fungus and frost. Certain trees from the 1953 inoculation experiments were subjected to frost at the point of inoculation to determine whether this would render relatively inactive cankers active. In a new set of experiments, potted trees of each of three strains of European larch were locally frost-damaged. One set was then exposed to cankers, one sprayed with a spore suspension, and one left as a control. A further set was inoculated with a culture of the fungus without being frozen. The effects of time of year and the wetness of the tree surface on susceptibility to both the fungus and frost are also being investigated.

A second cold frame has been constructed, and both frames have been equipped with thermohygrographs. This has enabled the stock of potted trees for future experiments to be increased to an adequate level.

Work has continued on the taxonomy of the British Trichoscyphelloideae, several of which are associated with conifer cankers and have been confused with *T. willkommii*. Type specimens, where extant, have been studied. No satisfactory key to the species exists, hence a provisional key has been constructed and is being tested: the results of the taxonomical work are being prepared for publication.

STUDIES IN THE MORPHOLOGICAL VARIATION OF CONIFERS

By Dr. E. V. LAING and Dr. A. CARLISLE
Department of Forestry, Aberdeen University

Lodgepole Pine (165.51)

RESEARCH has been mainly concentrated in this period on variations in the lodgepole pine, *Pinus contorta* Douglas, attention being focused principally upon the dimensions and anatomy of the needles. The main points being investigated in detail are the length and breadth of the needles, the thickness of the hypoderms, the occurrence of sclerenchyma in the stele, and the resin canals. As yet all the data have not been collected, but there are indications that it may be possible to prove that these vary to a statistically significant level between different provenances of the species. One important problem which has arisen is the effect of the site upon the structure of the needle. Investigations during the coming year should clarify this matter to a considerable extent.

Work has also been continued on the variations present in the cones and seed. This appears to be a promising field for research and it is intended to continue these studies.

One of the main difficulties connected with the work has been the location and collection of material suitable for examination. However, with the help of the Forestry Commission Research Branch some considerable progress has been made in this direction. At present, the provenance plots situated at Millbuie Forest on the Black Isle, Ross-shire, appear to be the most suitable for the purposes of the investigation. It is believed that an intensive examination of these plots will yield data of considerable interest, especially with regard to the response of the species to a foreign environment. Later it is hoped to augment the data collected at Millbuie by examinations of provenance plots in other areas.

Douglas Firs

The work on the genus *Pseudotsuga* has been continued. The main species with which we are concerned, *P. taxifolia*, *P. glauca* and *P. caesia*, are proving to be very variable and overlapping in their characters. Some intermediates between *P. taxifolia* and *P. glauca*, for instance, have characters which are more like *P. taxifolia* than *P. glauca*, whilst others have the reverse. An attempt is being made to find characters by which they can be recognised.

Scots Pine

The period 1954-55 was spent by Dr. Carlisle in the completion of the morphological studies of Scots pine and the preparation for publication of the data concerning the ecology of the native Scottish pinewoods.

Significant differences were found in the form of the micropilar tip of the Scots pine seeds, differences which are similar to those observed by Simak and other workers in Scandinavia.

Three hitherto unrecorded remnants of native pine forest were examined in the West of Scotland, near Ardgour; one of these is a forest of considerable extent.

Birches

Studies of the birch by Loch Rannoch (Perthshire) and Loch Garry (Inverness-shire) revealed that whilst both *Betula verrucosa* and *B. pubescens* occur in both localities, a great many trees could not be accurately assigned to either species. A preliminary study of the morphology of the birch showed that there are marked differences in the leaf form, the leaf serrations and the seed form, and these characters will be studied in more detail.

The germination of birch seeds in various media was investigated. It was found that a high soil moisture content is necessary during the first four weeks, and that even a brief period of drying of the soil surface results in the death of a high percentage of the plants.

BIOCLIMATIC STUDIES ON THE PINE LOOPER MOTH

By Dr. N. W. HUSSEY
Department of Agricultural and Forest Zoology, University of Edinburgh

(145.7: 151.1)

A STUDY of the effect of the physical environment on an insect involves an investigation of the relationship between the macroclimate, as measured at standard meteorological stations, and the microclimate of the habitat occupied in the various developmental stages. The egg and larval stages of the Pine Looper Moth, *Bupalus piniarius* L., are passed on two-year-old needles of Scots pine between June and October, and so attention has been confined to measurements of the temperature and evaporating power of the air in contact with such needles during the summer and autumn. These factors have been chosen for study as there is some evidence that optimum growth conditions result in heavier pupae and hence higher female fecundity in the next generation. Hitherto the exact physical limits of these 'optimum' conditions for larval growth have not been investigated.

Temperature measurements were made with thermistors to ascertain the difference between air and needle temperatures under different weather conditions. The influence of the position of the larva on the needle, as well as the orientation of the needle itself towards the sun, were investigated. In full sunlight, with the needle surface nearly perpendicular to the incoming radiation, needle temperatures were up to 3°F. above ambient air temperature. When the needles were shaded from direct sunlight, but remained exposed to the clear sky, temperatures ranged from 0.5° above to 1° below air temperature. As found by Wellington (1950), working on the Colorado spruce, *Picea pungens* Engelm., the intervals during which shaded needles remained above air temperatures were very short, and coincided with movements of the shading foliage which permitted some solar radiation to reach the measured surface. An example of the variations in temperature experienced by larvae in different situations on the needle, with different needle orientations, is illustrated in Table 11.

The effect of cloud naturally varies with both type and amount. Under heavy overcast skies, whether the clouds were stratiform or cumuliform, diffuse radiation maintained foliage temperatures fractionally above air temperature. In the bright periods associated with scattered stratocumulus clouds, considerable and rapid changes occur as shown in Table 12.

TEMPERATURE VARIATIONS AT DIFFERENT POINTS ON PINE NEEDLES

Table 11

	Needle perpendicular to radiation Degrees Fahrenheit			Needle approximately parallel to radiation Degrees Fahrenheit		
	Tip	Mid-point	Base	Tip	Mid-point	Base
Upper needle surface	68.5°	69.7°	69.7°	67.9°	68.0°	68.0°
Lower needle surface	68.0°	69.2°	69.0°	67.8°	68.0°	68.0°

TEMPERATURE VARIATIONS ACCORDING TO CLOUDINESS OF THE SKY

Table 12

	Degrees Fahrenheit								
Time a.m.	10.43	10.45	10.47	10.48	10.53	10.55	11.05	11.15	11.17
Weather	dull	sun	dull	dull	dull	v. dull	v. dull	sun	sun
Air temperature	59.5°	66.0°	62.0°	60.5°	60.5°	58.5°	57.5°	58.0°	66.6°
Needle temperature ...	59.4°	68.2°	62.8°	60.6°	60.5°	58.4°	57.3°	59.2°	69.4°

During rain, only negligible differences were recorded between air and needle temperatures, but evaporation of rain or dew lowered needle surface temperatures as much as 2° below air conditions for periods up to one hour. At night radiational cooling under a clear sky reduced needle temperatures to 1.5° below ambient conditions, but under overcast skies the temperatures were almost identical.

These figures illustrate the importance of cloud in influencing the physical environment of needle-feeding larvae which may, therefore, actually experience quite different amounts of heat under a variety of weather conditions for which standard meteorological stations return the same mean temperature.

Another important physical factor of the environment is the rate of evaporation. Despite difficulties of expressing results in comparable units, a useful guide to the physical conditions which must be simulated in laboratory equipment can be obtained if the same instrument is used to measure conditions both in the forest and in laboratory apparatus. The microevaporimeter used was a modified Piche type as developed by Wellington (1949) in which the evaporative rate is expressed in millimetres per minute (from a capillary tube 0.5 mm. in diameter). Wind speeds were measured with a Portable Air Meter, as manufactured by the Hastings Instrument Company of U.S.A., with which values of wind velocity could be determined a centimetre distant from individual needles. Various weather conditions were chosen for observations, in order to assess the range of evaporation rate within the larval habitat. In very moist conditions the evaporation rate naturally becomes almost *nil*, but in drier conditions considerable discrepancies develop between air and needle conditions, as shown in Table 13.

EVAPORATION RATES UNDER VARIOUS CLIMATIC CONDITIONS

Table 13

Temperature	% Relative Humidity (By Whirling Psychrometer)	Saturation Deficiency mm. Mercury	Average Wind Velocity feet/min.	Evaporation Rate in Free Air at Meteorological Station mm./min.	Evaporation Rate in Free Air within Crown Space mm./min.	Evaporation Rate within 2 mm. of Needle Surface mm./min.
53	96	0.4	0	0.30	0.25	0.20
55	90	1.0	700	1.00	0.47	0.40
52	81	1.8	150	1.39	1.35	1.15
54	80	2.0	100	1.40	0.98	0.81
58	80	2.2	200	1.75	1.54	1.34
58	79	2.3	500	2.32	1.88	1.59
56	68	3.0	700	2.85	2.14	1.80
60	73	3.3	80	1.94	1.32	1.00
60	69	4.0	250	2.09	1.76	1.46
63	70	4.2	450	2.90	2.38	1.88
65	63	5.6	100	3.10	2.62	2.00
67	57	6.1	500	3.90	3.30	2.90
68	45	9.5	550	5.80	5.10	4.60

Larvae were reared in the laboratory, at the extremes quoted in Table 13, to test the effect of evaporation on feeding and hence on growth rates. Larvae in instars one to three reacted by feeding faster in moister conditions, but the older larvae were not significantly affected.

At a constant humidity of 100 per cent, larvae of all instars fed more rapidly at higher temperatures, over the range 36 to 80°F.

The most convenient method of studying the effect of weather on feeding rate in the forest is to collect the frass produced by a known number of larvae in a given time. To facilitate these collections a coprometer, consisting principally of a clockwork turntable on which the falling frass was separated into hourly samples, was constructed. However, before the information on frass production can be translated into feeding rates it is necessary to determine the relation, both in time and quantity, between feeding and frass deposition in individual larvae. These studies suggested that larvae feed several times during the twenty-four hours, for about half an hour at a time. Actual consumption of food depends on larval size, but about 15 mm. length of needle is eaten entirely or merely scarified. Such a meal would not be excreted for three to five hours, but it has been well established that a heavy frass deposition indicates corresponding heavy feeding about two-and-a-half to three hours earlier. Such field observations as were made suggested that weather has a profound effect on feeding, the frass deposition differing by as much as fifty per cent on successive days.

The often quoted opinion that *Bupalus piniarius* tends to feed more at night was investigated, and the conclusion was drawn that, although such nocturnal peaks are evident at constant temperatures, under normal outdoor conditions diurnal feeding is far heavier than nocturnal feeding, due to the daily march of temperature.

Data were also accumulated on variations in fecundity, and incubation period and on mortality of eggs under different environmental conditions.

In the coming year attention will be concentrated on observations of larval feeding rate in the forest.

REFERENCES

WELLINGTON, W. G., 1949, Effects of temperature and moisture on behaviour of Spruce Budworm. *Sci. Ag.* 29, 201-215.

—, 1949, Temperature Measurements in Ecological Entomology. *Nature*, 163, 614-615.

—, 1950, Effects of Radiation on Temperatures of Insectan Habitats. *Sci. Ag.* 30, 209-234.

Douglas Fir Seedfly Studies

Following the work reported earlier (*F. C. Research Reports* 1951-53), the New Zealand forest authorities requested a supply of the principal parasite, *Amblymerus apicalis*, of the Douglas Fir Seedfly, *Megastigmus spermotrophus* Wachtl.

Cones were collected from Blackhall and Crathes Estates on Deeside, and from Novar and Rosehaugh Estates in Ross, during November, 1954, after the parasite had laid its eggs on the *Megastigmus* larvae within the seed. This material was flown out to New Zealand and some 1,800 parasites liberated at three centres. The New Zealand authorities are confident that it will establish itself in at least two of these areas.

SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY

Rothamsted Experimental Station, Harpenden

(114.67)

IN June, 1954, the writer received a grant to enable him to spend a year with Professor Kühnelt at the Zoological Institute of the University of Vienna. Whilst in Vienna time has been devoted to the development of a new culture method suitable for small soil-inhabiting animals such as the Acarina. The writer was invited to read a paper at the Symposium and Colloquium on Soil Zoology, held at the University of Nottingham School of Agriculture. He also staged an exhibit, and participated in practical demonstrations, etc.

A modified funnel apparatus for the extraction of soil meio- or meso-fauna has been developed and tested. The split-funnel extractor unit consists of an upper cylinder carrying an electric-light bulb, and a funnel with a removable sieve plate. These units are mounted in batteries of eighteen, in a wooden and metal framework. The cylinders are supported on a movable metal plate, counterpoised with weights, so that they can be raised and lowered to allow access to the funnels. The battery is thermostatically controlled, a thermostat being inserted in one funnel to provide reasonable temperature control over the whole battery. The principal advantages of this apparatus include: the desiccation process is easily controlled, and its direction is such that the desiccation front commences at the top and proceeds downwards through the sample; the apparatus is designed for small samples which can be easily and rapidly placed in position; lastly a special sample container and double sieve-plate arrangement prevents sample debris falling into the collecting tube.

The results of the effects of sample treatment on extraction efficiency are as follows: best results are obtained when litter and raw humus are put through the extraction process separately, the latter in thin layers (half to three quarter inch), in an undisturbed condition. There is little difference between the effectiveness of room temperature and a heated funnel (air temperature 30 to 35°C.) for extraction of litter, although with raw humus the latter is more effective. It is probably better to place raw-humus samples in the funnels in an inverted position. Poorest results are obtained when litter and raw humus are not separated, and the latter is in a disturbed condition. Delayed extraction of raw humus has a very deleterious effect. The funnels should be swept after extraction to recover organisms remaining on the sides. It was found that the time at which all the animals had left the raw humus is correlated with the level of sample desiccation (moisture content of about three to four per cent. of fresh volume), which in turn is a function of its volume, and therefore of the depth of the subsample. Disturbed samples take somewhat longer to dry, and the egress of animals extends over a much longer period. There is some evidence that individual treatments have had differing degrees of efficiency with certain oribatid species, and it is possible that a development of the concept of differential treatment might make the funnel method a more versatile tool than present evidence would suggest. It must be stressed that these findings were obtained with *Calluna* heathland samples, and do not necessarily apply to those from other habitats.

It is considered that both desiccation and temperature are important factors in the extraction process. The treatment results suggest that a temperature stimulus in the early stages of extraction is important, and that good recovery will depend upon striking a balance between a temperature which, although not providing a too rapid drying rate, is sufficient to cause a definite negatively thermotactic response. The great shrinkage of raw humus—up to forty per cent of the fresh volume—is a complicating factor, which may be responsible for the association of the best recovery of the animals with a definite temperature stimulus.

EFFECTS OF SHELTERBELTS ON MICROCLIMATE

By J. M. CABORN

Department of Forestry, University of Edinburgh

(266: 111.84)

THE study of the effects of shelterbelts on the microclimate of adjacent areas has been continued. The object of this investigation is the collection of evidence as to the best site, type and structure of shelterbelt which would afford the most efficient shelter, particularly for stock-rearing or afforestation on upland areas.

The following programme was formulated for the first three-year period:—

(*a*) To review the evidence concerning the effects of shelterbelts on microclimatic factors and their influences on agricultural yields and forestry practice.

(*b*) To consider the applicability of previous research to requirements in Great Britain and to consider further research from a forestry aspect.

(*c*) To examine experimental technique and instrumentation for the study of the various physical factors of microclimates—wind velocity and direction, atmospheric temperature and humidity, evaporation and transpiration, soil moisture and temperature, and snow distribution.

(*d*) To investigate the influences on microclimate, particularly wind conditions, of existing shelterbelts of different width, structure and composition by species, with a view to determining the optimum belt structure.

(*e*) To study wind conditions in regions of irregular topography so as to determine the most suitable situation for belts.

(*f*) To consider the application of shelterbelts to forestry, both for shelter on exposed sites scheduled for afforestation, and of protective margins and internal wind-firm strips in the established forest.

The field investigations proposed under items (*d*), (*e*) and (*f*) above, must be considered long-term. Although certain general conclusions on individual features of shelterbelt design may be permissible as a result of short-term observations, exhaustive information on the inevitably slow process of developing the appropriate structures by means of planting and subsequent treatment, and also on the siting of belts to meet the varying requirements of topography on hill and upland areas, cannot be expected for some years.

Review of literature and certain modifications and developments of research procedure have been done during the year, but attention has been concentrated mainly on the experimental work. Through the co-operation of Professor P. A. Sheppard, facilities were made available at the Department of Meteorology of the Imperial College of Science and Technology, London, for the examination of some of the fundamental problems of shelterbelt design by means of wind-tunnel studies. These investigations may be regarded as a basis for subsequent field research. Data obtained under natural conditions, though less conclusive and frequently less easily interpreted, must continue to form the major part of the research. The purely physical approach, however, can greatly assist the analysis of field data by isolating some of the basic features of shelterbelts, such as their relative dimensions and shape.

In September the author studied shelterbelt practice in Switzerland, and also joined Dr. W. Nägeli of the Swiss Forest Research Institute in similar field research on the Plain of Orbe and in the Rhine Valley.

Research Technique

Few modifications have been necessary to the standard field technique detailed in the last report, particularly with regard to wind studies. Two 'Sensitive Type IV' anemometers (Casella & Co., London) were loaned by the Meteorological Office in June for a period of one year, and two further instruments of the same type were purchased in August, thus bringing the number available to five. This has resulted in an improvement in the execution of the field studies and in the reliability of the data. With the twenty or so observation points required to cover adequately the zone of influence of a shelterbelt, it has been possible to spread these over five measurement periods, generally of thirty minutes each. During the operation one anemometer has to be set up at a control position, together with a direction vane; all other readings are based on the control values for the particular period of measurement. There are certain disadvantages to this method, notably that the wind velocity values recorded at all stations are not simultaneous and, therefore, may be complicated by changes in wind direction. Theoretically, direction variations can be allowed for, and corrections applied to the readings. In practice, the mean wind direction for the measurement period is taken. However, wind conditions frequently exhibit marked fluctuations, which cannot be taken into account even if the direction of the wind were noted every two or three minutes, and the average of these directions calculated at the end of the half-hour. These restrictions, which may reduce the accuracy of the data obtained to a degree depending upon the prevailing meteorological conditions, must be accepted with the equipment available. In Switzerland, where the complete measurement line is equipped with anemometers at the one time, all instruments are read every thirty minutes, and, with an automatic wind direction recorder established at the control station on the open ground, it is possible to reject any half-hour periods when the wind direction showed too marked a deviation from that normal to the shelterbelt, and to take the mean of the more favourable periods during the day.

It was thought originally that temperature and humidity conditions near shelterbelts merited investigation but it has since been decided to abandon short-term observations. Changes in plant cover on the two sides of a shelterbelt are not conducive to comparative measurements of air temperature and relative humidity near the ground, with the object of determining the shelterbelt influence on these factors. It has been considered more appropriate to study a factor which integrates wind, temperature and humidity conditions, and their continual fluctuations, and does not rely on instantaneous measurements, i.e. evaporation rate. This may serve as the most useful index of shelterbelt efficiency and its study appears more suitable to our purpose. It would seem that it is the desiccating or evaporative power of the wind which is critical for vegetation and, similarly, the cooling power or 'exposure' factor which is detrimental to animal welfare. Apart from the reduction of mechanical damage to plant life brought about by shelterbelts, it is the diminution of the evaporative power of the wind which largely constitutes 'shelter'.

The types of evaporimeter available commercially are either expensive or of limited practical use. A new design of instrument, attributed to Dr. W. Nägeli of the Swiss Forest Research Institute and used with considerable success in that country, has been modified for our use and manufactured locally. Comparative values only are required and no attempt has been made to determine absolute evaporation.

The two factors of microclimate, wind and evaporation, are now the main objects of study. At a later date it may be possible to conduct temperature measurements in the vicinity of selected shelterbelts, particularly to assess their influence on ground frost.

Investigations

Laboratory Investigations

The two aspects of shelterbelt design which have been examined in wind-tunnel experiments are width and cross-sectional shape, the latter also in relation to stand margins. The question of the ideal shelterbelt width is a matter of importance in the upland areas, where it may be assumed that the area of land which can be devoted economically to a shelter plantation is a less critical factor than it is on more valuable arable ground. These investigations have attempted to clarify the role played by width in determining the extent of the sheltered zone to leeward of a shelterbelt. Similarly, the American 'gabled-roof' construction of belts, with the tallest trees in the centre, has received a great deal of publicity; in the wind-tunnel investigations various cross-sectional designs have been compared, in their effect on wind velocity abatement, with the conventional belt of uniform height throughout.

Field Investigations

Field work is complicated by the fact that many otherwise suitable shelterbelts are situated on irregular ground which does not permit the collection of comparative microclimatic data which can be attributed entirely to the presence of the shelterbelt. Within systems of shelterbelts, as occasionally found on the Pentland Hills and elsewhere, it is frequently impossible to obtain a velocity value for the unobstructed wind, on which to base other measurements. In other cases, the presence of buildings and obstacles upwind of the shelterbelt prevent accurate study; gaps in several belts interfere with the laying out of a suitable measurement line. However, some useful information has been collected.

With the assistance of Forestry Commission staff, several shelterbelts in the Border districts have been selected for future study: these will add considerably to the variety of belt types already under observation.

Conclusions

As a result of detailed investigations of the physical foundations of shelter effect, carried out in America, Denmark, Russia and Switzerland, information is now available in respect of the relationships of shelterbelt height, penetrability and length to the sheltered area. Following on previous research, the wind-tunnel studies described above, when substantiated by field research on suitable plantations, should clarify the width and the cross-sectional profile relationships. This knowledge should assist very greatly the interpretation of wind conditions in the neighbourhood of individual shelterbelts, and promote the assessment of the particular belt structures involved. It should help also to give general guidance on the geometric proportions to be achieved in new shelterbelts, in so far as they can be dissociated from vegetative structure and composition.

An important consideration, however, must be the practical value of the investigations with regard to the immediate improvement of degraded and inefficient belts, of which there is a high proportion at the present time. In this connexion, a simple 'rule of thumb' method is required for the assessment, in the field, of the protective efficiency of existing belts. A provisional method of assessment has therefore been formulated, based on the examination of the wind velocity field in the vicinity of shelterbelts. Hence it is possible to determine the 'penetrability class' into which the belt falls. According to the degree of permeability desirable in a particular case, and after study of the site factors and the silvicultural condition, by which is meant the composition by species and development stage, it should be possible to prescribe the appropriate cultural treatment, whether it be thinning, interplanting or marginal improvement.

Regarding shelter for forestry areas, the climatological implications of stand margins require further definition. It is evident that this aspect differs somewhat from the employment of shelterbelts in agriculture. In the latter, the shelter is required near the ground, say within the lowest six feet of the atmosphere. In forestry, shelter is required near the ground mainly for new plantations on exposed ground. In the established forest the protection is required at all levels from ground to crown level, and even above the tree canopy when we consider the prevention, or at least the mitigation, of wind damage.

Part III. Reports on results of Individual Investigations

LONGEVITY OF ACORNS WITH SEVERAL STORAGE METHODS

By G. D. HOLMES and G. BUSZEWICZ

(232.315.2)

IRREGULAR seeding of oak, and the incidence of good mast years only at intervals of two to four years, sets a number of practical problems. It can result in difficulties in ensuring a regular supply of plants for the annual planting programme, and may lead to plant gluts or shortages according to the size of the seed crop in the previous year. Such difficulties can be overcome by sowing large quantities of acorns during mast years and storing the plants in the nursery, with regular root pruning or transplanting to maintain the plants with a well balanced root and shoot. However, this is not a complete answer, as it is expensive, and may result in an undesirable type of planting stock. The only fully satisfactory solution to the problem would seem to be storage of acorns for one, two, or more seasons to ensure adequate supplies for the annual seed sowing programme. It has not been possible to store acorns in this way in practice, as usually they do not survive more than six to nine months with normal short-term storage methods. Accordingly, in autumn 1950, a trial was started to study the longevity of acorns of *Quercus robur* L. under a range of storage conditions.

The conditions for short-term storage of acorns have been the subject of many experiments, and a useful review can be found in the works of Hauch (1935), Korstian (1927 and 1930), Tyszkiewicz (1951 and 1952), and Messer (1952). Most methods involve maintaining acorns under equable temperature and moisture conditions, and include such techniques as spreading the seeds in a cool shed, or stratification in moist sand or peat in a pit or a cool room. A general account of the methods of short-term storage used by the Forestry Commission has been given in Forestry Commission Leaflet 28 (1951).

Both temperature and moisture are critical factors in storage, and it is difficult to consider them separately as each interacts with the other. Generally a moderately low, equable temperature, and high atmospheric humidity, appear most favourable for maintenance of viability under natural and artificial conditions. Extremes in the moisture content of either acorns or atmosphere are to be avoided. High seed moisture may result in the seed going mouldy, or heating-up in storage, and at the other extreme, excessive drying will result in rapid death of the acorns. Messer (1952) demonstrated the sensitivity of acorns to drying, and indicated the lowest moisture content tolerated without injury as: red oak—twenty per cent; sessile oak—twenty-two per cent; pedunculate oak—twenty-five per cent. Tyszkiewicz (1952) suggests that stored acorns should not exceed forty-five per cent moisture content. Schmidt (1931) gives a maximum of forty per cent, while Jenz (1933), who continued Schmidt's work, indicates that forty-five to fifty per cent is the best moisture content for acorn storage.

Storage temperatures just above freezing point have given good results and Korstian (1927) considered the best storage temperature for oak to be 33 to 38°F.

Sub-freezing temperatures have not been extensively tried but Pravdin and Filimonova (1952) report that acorns stored four months at 19°–41°F. showed a gemination of 94 to 100 per cent. A supply of oxygen for seed respiration is essential in storage, and one of the main effects of a low temperature is to decrease respiration and the rate of destructive metabolism. This was well demonstrated by Zaiceva (1950) who showed a steep rise in the respiration and carbon dioxide production of acorns with an increase in temperature from 0° to 20°C. She suggested that there is a critical point beyond which an increase of carbon dioxide in the storage atmosphere will have a toxic effect owing to initiation of anaerobic respiration. Storage for periods exceeding one year have not been widely investigated. Johannsen (1921) showed that he was able to keep acorns in sacks at a constant temperature of 34°–36°F. for more than two years, but a gradual decrease of germination occurred. He emphasised that acorns should not be allowed to dry and that they should have free aeration during storage. Holten (1920) concludes that acorns can be stored for two years, if, during the first winter, Hauch's dry storage method is used, followed by stratification of the acorns in dry sand, at some depth, to ensure a fairly constant temperature.

Trials with a Range of Storage Methods for Acorns

Two trials were carried out, one started in 1950 and the other in 1952, the latter following up the best treatments found in the 1950 trial.

The 1950 Trial

Acorns were collected in September, 1950, and thoroughly cleaned, removing all damaged and diseased seeds. This cleaned seed showed a sound seed percentage of ninety and a moisture content (on wet weight) of fifty per cent, just before it was placed in storage. The cleaned acorns were then divided into ten-pound lots, and placed in large biscuit tins for storage tests under the following conditions:—

(1) *Constant temperature* 10°*F.*
- (*a*) Stored in ice.
- (*b*) Stored in a sealed tin.
- (*c*) Stored in slightly moist peat in an unsealed tin.

(2) *Constant temperature* 25°*F.*
- (*a*) Stored in a sealed tin.
- *b*) Stored in slightly moist peat in an unsealed tin.

(3) *Constant temperature* 36°*F.*
- (*a*) Stored in a sealed tin.
- (*b*) Stored in a sealed tin, seed dried to forty per cent moisture content.
- (*c*) Stored in slightly moist peat in an unsealed tin.
- (*d*) Stored in dry peat in an unsealed tin.
- (*e*) Stored in slightly moist sand in an unsealed tin.

(4) *Unheated room*
- (*a*) Stored in a sealed tin.
- (*b*) Stored in an unsealed tin.
- (*c*) Stored in a sealed tin, seed dried to forty per cent moisture content.

Samples were removed from the several storage containers after six months, eighteen months, and thereafter at intervals of six months, over a total of forty-two months, or three-and-a-half years, storage. On each occasion, after inspection of the general condition of the seed and the stratification media, the seed samples were subjected to moisture and germination tests. Seed moisture content was determined by drying out seeds to constant weight at 221°F. Germ-

THE MOISTURE CONTENT AND GERMINATIVE CAPACITY OF ACORNS DURING FORTY-TWO MONTHS OF STORAGE BY VARIOUS METHODS—NOVEMBER 1950 TO APRIL 1954

Table 14

No.	Temperature °F.	Storage Method	Initial Test Nov. 1950		After 6 months April 1951		After 18 months April 1952		After 24 months Nov. 1952		After 30 months April 1953		After 36 months Nov. 1953		After 42 months April 1954	
			Moisture Content %	Germination %	Moisture Content %	Germination %	Moisture Content %	Germination %	Moisture Content %	Germination %	Moisture Content %	Germination %	Moisture Content %	Germination %	Moisture Content %	Germination %
1A	10°	In ice	45.9	90	46.5	Nil	Discarded, dead									
1B	10°	Sealed tin	45.9	90	48.7	1	Discarded, dead									
1C	10°	Moist peat, unsealed tin	45.9	90	43.5	Nil	Discarded, dead									
2A	25°	Sealed tin	45.9	90	43.2	42	Discarded, dead									
2B	25°	Moist peat, unsealed tin	45.9	90	51.2	43	Discarded, dead									
3A	36°	Sealed tin	45.9	90	44.8	88	52.6	Nil	Discarded, dead							
3B	36°	Sealed tin (seed dried)	40.5	90	40.1	1	Discarded									
3C	36°	Moist peat, unsealed tin	45.9	90	49.2	88	52.8	72	56.5	80	58.2	68	—	68	69.6	24
3D	36°	Air dry peat, unsealed tin	45.9	90	44.8	87	44.8	62	46.2	73	43.2	61	—	71	48.4	52
3E	36°	Moist sand, unsealed tin	45.9	90	52.4	79	64.3	65	63.5	67	64.5	51	—	43	58.3	11
4A	Cool room	Sealed tin	50.0	90	47.9	84	Discarded, dead									
4B	Cool room	Unsealed tin	50.0	90	58.3	64	Discarded, dead									
4C	Cool room	Sealed tin (seed dried)	40.5	90	43.5	Nil	Discarded, dead									

ination tests were carried out in soil beds under controlled temperature conditions in a greenhouse. In the spring of 1954, after forty-two months storage, there were only about 300 acorns of each treatment left in store, and it was decided to use these for a final germination test by sowing the seeds in the open in a nursery bed.

Results

The results of moisture content and germination tests are shown in Table 14.

It can be seen from Table 14 that acorns stored at 10°F. were among the first to die. This temperature proved deadly, irrespective of the method of storage, and all acorns died within the first six months of storage. A temperature of 25°F. was a little less harmful. Seed viability was reduced by fifty per cent during the first six months, and all seeds were dead after eighteen months. Similarly poor results were obtained from storage in an unheated room. The acorns survived six months storage quite well, except the dried ones, but failed to survive for eighteen months.

The best results were obtained at a temperature of 36°F., in which three methods, out of the five tested, showed living acorns after forty-two months storage. Storage in air-sealed containers at this temperature failed between six and eighteen months, and acorns dried to forty per cent moisture content before sealing were nearly all dead after six months. Unsealed containers with a dry stratification medium proved the most suitable method. Using dry peat as the medium, there was a forty per cent reduction in seed viability after three-and-a-half years' storage. After three years the reduction was only twenty per cent. Storage in a moist stratification medium of sand or peat at 36°F. was rather less successful but showed a high seed survival after three years with a sharp drop at three-and-a-half years.

It can be seen from Table 14 that storage at 36°F. in dry peat resulted in a very small variation in seed moisture content which was maintained at forty-six to forty-eight per cent throughout the period of storage. Acorns stored in moist peat or sand at the same temperature showed a gradual increase of seed moisture from 45.9 per cent at the start to 69.6 per cent for moist peat, and 58.3 per cent for moist sand, after forty-two months' storage. This increase in moisture content resulted in pregermination, and in the development of surface moulds on the seeds. The extent of pregermination and radicle development on acorns from these three best storage methods can be seen in Photos 15, 16, and 17. These illustrate the condition of seeds removed after three-and-a-half years' storage. Acorns stored in the moist media (Photos 16 and 17) showed darkening, softening, and extensive longitudinal splitting of the testa, compared with the hard intact testas found on most seeds in dry peat (Photo 15). All seed lots show pregermination, and those stored in dry peat started to pregerminate only after one-and-a-half years' storage, compared with those in the moist media which showed radicle development after six months' storage.

Pregermination does not appear to affect the viability of the acorns after removal from storage. This point was checked by photographing and retaining the identity of each seed sown in the final germination test after three-and-a-half years' storage. The acorns which produced seedlings in these tests are ringed in Photos 15, 16, and 17. It will be seen that the great majority of the acorns which germinated in the final test had pregerminated in storage and in many cases showed a large radicle development. A temperature of 32°F. would probably be necessary to prevent pregermination during such long storage periods.

The 1952 Trial

In the second tests, which were started in 1952, an effort was made to extend the trials of those methods showing the best results in the 1950 series. A consignment of acorns showing ninety per cent viability and a seed moisture content

Table 15

THE MOISTURE CONTENT AND GERMINATIVE CAPACITY OF ACORNS DURING THIRTY MONTHS OF STORAGE BY VARIOUS METHODS—NOVEMBER 1952 TO APRIL 1955

Stratification Medium	Storage Temperature (°F.)	Initial Test Nov. 1952		After 6 months April 1953		After 12 months Nov. 1953		After 18 months April 1954		After 30 months April 1955	
		M.C. %	Germ. %	M.C. %	Germ. %	M.C. %	Cutting Test	M.C. %	Germ. %	M.C. %	Germ. %
Air-dry peat	36°	44.4	90	49.8	70	—	90	54.3	70	64.8	67
Air-dry peat	36°	47.4	90	48.7	71	—	73	57.4	65	53.9	72
Air-dry peat	36°	50.0	90	53.2	81	—	85	53.6	67	56.5	82
Air-dry peat	Unheated room	44.4	90	49.4	67	Disc.	dead				
Air-dry peat	Unheated room	47.4	90	49.4	76	Disc.	dead				
Air-dry peat	Unheated room	50.0	90	51.9	80	Disc.	dead				
Air-dry sand	36°	44.4	90	52.0	78	—	85	51.5	67	51.4	65
Air-dry sand	36°	47.4	90	53.0	72	—	78	55.7	80	56.3	68
Air-dry sand	36°	50.0	90	55.0	70	—	78	53.8	81	47.6	61
Air-dry gravel	36°	44.4	90	46.6	70	—	70	48.5	73	48.3	58
Air-dry gravel	36°	47.4	90	48.0	85	—	78	49.4	72	42.7	77
Air-dry gravel	36°	50.0	90	50.2	77	—	85	48.4	69	38.9	35
Air-dry sawdust	36°	44.4	90	53.1	78	—	85	62.3	84	64.3	74
Air-dry sawdust	36°	47.4	90	54.9	71	—	80	63.5	78	62.6	86
Air-dry sawdust	36°	50.0	90	56.3	75	—	83	64.4	82	66.3	74
Air-dry sawdust	Unheated room	44.4	90	55.3	78	Disc.	dead				
Air-dry sawdust	Unheated room	47.4	90	55.1	79	Disc.	dead				
Air-dry sawdust	Unheated room	50.0	90	57.1	82	Disc.	dead				
Moist peat	36°	47.4	90	57.0	83	—	75	66.5	72	68.7	81
Moist sand	36°	47.4	90	60.2	78	—	68	66.3	62	66.9	61
Moist gravel	36°	47.4	90	56.5	68	—	70	62.3	10	Disc.	dead
Moist sawdust	36°	47.4	90	57.8	71	Disc.	rotten				
Additional Tests: Seeds stored in:—											
1. Waterglass	36°	47.4	90	55.7	33	Disc.	rotten				
2. Carbon dioxide (sealed)	36°	47.4	90	48.9	0	Disc.	rotten				

M.C. = Moisture Content. Germ. % = Germination %. Disc. = Discarded.

of forty-seven per cent was selected, and all bad, damaged, and pregerminated seeds were removed before storage tests started. As in 1950, the seeds were thoroughly mixed, and were divided among a number of large tins which were then allotted at random to the various conditions and methods of storage. A storage temperature of 36°F. was used throughout the main part of this trial, and the principal aim of the trial was to compare several types of stratifying media when used in an air-dry or moist condition. Seeds to be kept in air-dry media were adjusted to three different levels of moisture content before being placed in the medium. The first lot was dried to forty-four per cent, the second was moistened to fifty per cent, and the third stored at the initial moisture content of forty-seven per cent. In a subsidiary test two seed lots were kept in waterglass, in the manner used for egg storage, and a further two were stored in an atmosphere of carbon dioxide, as a check on the possibilities of this method of storage. Seed samples from all treatments were examined at intervals from November, 1952 to May, 1955. The results of tests on these samples are summarised in Table 15.

The periodical tests of seed moisture and germination were carried out on the same lines as in the previous trial, except that a cutting test was substituted for the germination test on the samples taken in November, 1953. The test results show a similar trend to those in the 1950 experiment, i.e. an unheated room is unsuitable for long storage and an air-dry stratification medium is superior to a moist one. The trial with waterglass was unsuccessful, as two-thirds of the seeds lost their viability within six months in this medium. Storage in an atmosphere of carbon dioxide was a complete failure, and all acorns died within six months. Seeds stored in moist media varied considerably according to the stratifying material used. Seed in moist peat or sand was satisfactory, although there was a considerable increase of seed moisture content. Storage in moist gravel, or sawdust, at 36°F., was fair up to six months, but after eighteen months' storage the acorns in gravel showed only ten per cent viability, and those in moist sawdust were all dead within twelve months.

Acorns stored in dry media at 36°F. did not show striking differences in seed quality between treatments after eighteen months' storage. The seed moisture content had increased in all media, and the arranged differences in seed initial moisture content were obscured. The usual seed moisture increase was particularly marked in sawdust, but a small decrease occurred in air-dry gravel. The moisture content of seed in air-dry peat had increased appreciably after eighteen months, the increase being greater than that observed in the same period in the 1950 trial (see Table 14). This is probably due to a higher initial moisture content of the air-dry medium in 1952, owing to higher atmospheric humidity at the time the medium was prepared.

Conclusions and Summary

In the thirteen methods tried in 1950, the acorns died within twelve months in all except three methods, and in these, viable seeds were present after forty-two months' storage. The best methods involved storage at 36°F., the acorns being stratified in dry or moist peat or sand. The most satisfactory of these treatments was storage in air-dry peat, in which acorns showed only twenty per cent loss of viability after thirty-six months' storage. Acorns stored in air-dry peat also showed the smallest fluctuation in seed moisture content, which remained between forty-five and forty-eight per cent throughout the period of storage. A moisture content of about forty-five per cent seems most satisfactory for prolonged storage. A higher moisture content can be quite satisfactory for up to eighteen months, but thereafter the seeds deteriorate rapidly or show extensive pregermination.

To sum up the experience gained in the 1950 and 1952 trials, it seems possible to keep acorns alive for three years without serious loss of viability, providing the following conditions are fulfilled:

(1) A constant temperature of 36°F. is maintained.
(2) The moisture content of the acorns lies within forty to forty-five per cent (on fresh weight).
(3) The acorns are stratified in dry peat or sand in a closed but unsealed container.
(4) Acorns for prolonged storage should be of good quality and free from disease or damage.

Moreover, it can be stated that the following conditions are unsuitable for prolonged storage:—

(1) An atmosphere of carbon dioxide.
(2) Storage temperatures below freezing point, or an unheated room.
(3) Storage in sealed containers at any temperature.

REFERENCES

FORESTRY COMMISSION (1951). *Collection and Storage of Acorns and Beech Mast.* For. Com. Leaflet No. 28. H.M.S.O.

HAUCH, L. A. (1935). *The Oak in Denmark.* Gyldendalske Boghandel.

HOLTEN, A. (1920). Two Years Storage of Acorns. *Dansk. Skov. Tidsk.* 5 : 191-8.

JENZ, O. (1933). Storage Methods for Hardwood Seeds. *Deutsch. Forstwirt.* 15: (237-9).

JOHANNSEN, W. (1921). Experiments in Storing Acorns and Beechnuts. *Det. Forstlige Forsogvesen. i Danmark* 5: (372-90).

KORSTIAN, C. F. (1927). *Factors Controlling Germination and Early Survival of Oak.* Yale Univ. For. School, Bull. No. 19.

—— (1930). Acorn Storage in the Southern States. *Journ. For.* 28: (858-63).

MESSER, H. (1952). *Storage of Acorns and Beechnuts.* J. D. Sauerlander, Frankfurt on Main.

PRAVDIN, L. F. and FILIMONOVA, V. D. (1952). The Influence of Low Temperature on the Viability of Acorns. *Dokl. Akad. Nauk. U.S.S.R.* 85 (4): 1952 (921-4).

SCHMIDT, W. (1931). Storage Methods for Hardwood Seeds. *Deutsch. Forstwirt.* 13: 562-5.

TYSZKIEWICZ, S. (1951). *Storage of Forest Tree Seed.* Agriculture and Forestry Publications, Warsaw 1951.

—— (1952). *Forest Tree Seed.* Agriculture and Forestry Publications, Warsaw 1952.

ZAICEVA, A. A. (1950). Winter Storage of Acorns. *Lesn. Hoz.* 3 (10), (63-72).

COMPARISON OF SHELL "D.D." WITH FORMALIN AS A CONIFER SEEDBED PARTIAL SOIL STERILISER

By R. FAULKNER

(232.322.2)

IN 1949 it was suggested that the proprietary chemical, Shell D.D. soil fumigant, which had been successfully used as a partial soil sterilising agent in agricultural practice and later reported on by Newhall (1946), and Jacks (1953), and in *Notes* *from Auchincruive* (1954), might possibly find a place in forest nurseries as a cheaper and more effective material than formalin, which hitherto had shown promise in conifer seedbeds (Edwards, 1952). The series of experiments to be discussed were designed to compare Shell D.D. with formalin. The mean height and total yield of seedlings, and the time taken to weed plots within the experiment, were used as factors for determining the relative efficiency of the chemical.

Notes on the Sterilisers and the Methods of Application

(*a*) **Shell D.D.** Shell D.D. Soil Fumigant (dichloropropane-dichloropropylene) is a liquid mixture of chlorinated hydrocarbons derived from petroleum, which vaporises into a gas when injected into the soil. The rate of vaporisation is governed by the soil temperature, and previous agricultural experience has shown that a period of four weeks or longer must elapse before sowing seed in spring on D.D.-treated soil. In these experiments an interval of twenty-four to thirty days was allowed between the time of injection and the date of sowing, and in all cases the soil was well cultivated to a depth of five inches, several days before sowing, in order to permit any residual vapours to escape.

The method of application was by means of a manually operated Shell D.D. injector gun set to force known volumes of the D.D. into the soil at a depth of six inches. Numbers of injection points per square yard varied in the different experiments, as detailed below.

The recommended rate of application for agricultural purposes is 400 lb. of D.D. per acre, but in this series of experiments rates of from 150 to 600 lb. per acre were tested.

(*b*) **Formalin.** Formalin is sold as a thirty-eight per cent solution of formaldehyde in water and this was applied, diluted in water, in the ratio of 0.1 gallon formalin to 1 to 2 gallons of water, per square yard (480 gal. formalin per acre). This had proved most satisfactory in previous soil sterilisation experiments. The amount of added water varied according to the condition of the soil at the time of application. If the soil was very wet, only one gallon was used; if the soil was very dry, two gallons of water were used; and, if medium, one and a half gallons were used. The diluted solution was applied to the seedbeds, with a garden watering can fitted with a rose, on the same date as the D.D. treatments.

Experimental Procedure

Each year, seedbeds three feet six inches wide were prepared in early spring and, after levelling, the steriliser treatments were applied to the respective randomised plots, using a standard three feet six inches square plot for sterilisation. A few days before the expected sowing date, all the plots were cultivated to permit residual vapours to escape, and at the same time phosphate and potash fertilisers were applied in order to ensure that potash and phosphate supplies would be adequate for the needs of the crop of seedlings. Sitka spruce was used throughout as the indicator species, and this was sown on the centre square yard of each plot and covered with $\frac{3}{16}$ inch of coarse sand or grit.

The experiments were carried out in 1950 and 1951 in nurseries at Inchnacardoch, Inverness-shire; Newton, Morayshire; Benmore, Argyll; Tulliallan, Fife; and Fleet, Kirkcudbrightshire. In 1952 only four centres were used; Tulliallan was the nursery omitted.

The 1950 Series of Experiments

In the first-year experiments, D.D. was used at rates of 150, 300 and 600 lb. per acre, and was injected using either three lines of injection points per three feet six inch width of seedbed (eight equidistant injection points fourteen inches apart), or two lines of injection points (four equidistant injection points twenty inches apart). After injection, the liquid was sealed into the soil either (*a*) by uniformly trampling over the whole plot or (*b*) by sealing it with an application of water at two gallons per square yard. These three groups of treatments were factorially combined and compared with formalin-treated and with unsterilised plots, the last two treatments being factorially combined with the compaction and water sealing treatments. The resulting sixteen treatments were replicated in four blocks.

At the end of the growing season it was found that neither of the soil sealing treatments had produced any significant effect upon height growth or yield of seedlings, nor upon weeding times in the plots. There were no significant effects upon the seedlings between the two spacings of injection points. But at Inchnacardoch and Benmore respectively there were significant (twenty per cent level of significance) and highly significant (one per cent level of significance) reductions in weeding times when two lines of injection points were used instead of three. There were no significant height differences between the three rates of application of D.D. at any of the nurseries. At Benmore the 600 lb. per acre treatment caused a highly significant reduction in the total numbers of seedlings in comparison with the 150 lb. per acre application; at Newton the reduction was significant, yet in the remaining three nurseries the reductions were similar in trend but not significant statistically. Weeding times were significantly reduced at Benmore by the 600 lb. per acre treatment when compared with both the 300 and 150 lb. per acre treatments. The indications were, therefore, that the higher concentrations were, at certain nurseries, inimical, either to weeds, or to tree seedlings or to both weeds and seedlings.

In comparison with non-sterilised plots, the average of all three levels of D.D. significantly increased the mean heights of seedlings at Inchnacardoch, Newton and Benmore; only at Tulliallan, however, were seedlings raised on D.D.-treated soil actually taller than those raised on formalin-treated soil. Even so the differences were not statistically significant. D.D. significantly reduced total numbers of seedlings at Newton and Benmore only. In addition D.D. significantly reduced weeding times at Benmore and Fleet, but it was less effective as a weedkiller, in these nurseries, than formalin. (See Table 16.)

The 1951 Series of Experiments

Because there were no important differences between the two sealing treatments in 1950, they were excluded from the 1951 experimental plan. Instead, all D.D.-treated plots were lightly trampled in order to reduce the speed of D.D. losses from the soil. Otherwise the plan remained the same, and contained eight plots replicated in four blocks. Sitka spruce was again used as the indicator species. The method of spacing the injection points for D.D. had no significant effect upon the subsequent height growth of the seedlings.

At Inchnacardoch and Benmore both formalin and DD. treatments significantly increased the heights of seedlings, but formalin produced significantly taller plants than did D.D. At Newton only, D.D. significantly increased the mean heights of plants, and formalin had no appreciable effect; whereas at Fleet only formalin significantly increased mean heights, D.D. having no appreciable effect. When comparing the three levels of D.D. at Inchnacardoch, it was found that 300 and 600 lb. per acre rates produced significantly taller plants than did the 150 lb. per acre treatments. At Benmore, Newton and Fleet the increases at higher levels were small and not significant.

The yield of seedlings was only affected to any notable extent at Inchnacardoch, where formalin gave a significant increase in numbers compared with D.D. and with unsterilised plots. This was probably due to the reduced crop of weeds on the formalin-treated plots, which resulted in smaller losses of seedlings when weeding. There were no appreciable differences in the yield of seedlings raised on plots treated with the three concentrations of D.D.

Weeding times were greatly reduced by formalin at all nurseries; and to a much smaller extent by D.D., but only at Benmore and Fleet (See Table 17).

1952 Extension of the 1952 Experiments

Plants raised on the 1951 experiment at Newton, Benmore and Fleet were carefully lifted in spring, 1952, and the plots were resown after additions of artificial fertiliser had been applied to all plots. At the end of the year it was recorded that there were no residual effects of any sterilisation treatment at Newton, but at Fleet and Benmore both formalin and D.D. plots had significantly taller plants than the control. At Benmore the difference between formalin and the mean of all D.D. plots was small, but at Fleet the residual effect of formalin was more pronounced than that of the D.D.

The 1952 Series of Experiments

The treatments were again altered in 1952. Instead of three concentrations of D.D. two concentrations were used. These were 300 lb. per acre, and 450 lb. per acre. Previous results had shown 150 lb. per acre was not enough and that 600 lb. per acre was sometimes harmful or did not produce a proportionate benefit in relation to its cost.

All injections were made by eight equidistant injections per plot spaced along three lines. Previous results had shown that in general there were no significant differences between two and three lines of injection points per bed.

One new treatment was included, this was the cultivation of the soil by forking to a depth of five inches, twenty-four hours after applying the D.D. It was thought that such a treatment would permit a more thorough penetration and mixing of D.D. vapours throughout the soil, thus increasing the sterilisation effect of the D.D. In effect there were no differences, except at Newton where the cultivated plots did produce significantly taller seedlings.

Formalin sterilisation was also included in the experiment, which was designed factorially.

The experiment was carried out at Inchnacardoch, Newton, Benmore and Fleet. Results showed (see Table 18) that formalin produced the tallest seedlings at all nurseries. The difference in height between the formalin and the control plots at Inchnacardoch, Benmore and Fleet was highly significant. The differences between D.D. and the control, when D.D. was applied at 450 lb. per acre (the most successful of the two concentrations of D.D.) were highly significant only at Inchnacardoch and Benmore. At Inchnacardoch and Fleet formalin produced very much taller seedlings than did the best of the D.D. treatments.

The yield of seedlings, by number, was not significantly affected by any of the treatments at any nursery.

At Fleet, formalin led to less weeding, but at both Fleet and Benmore, D.D. increased the amount of weeding to be done. The reason for the increased weeding is obscure. In addition, weeding times at Fleet were significantly increased by the soil cultivation treatment. (See Table 18).

Conclusions

From the data presented it is clear that Shell D.D. has some sterilising action on nursery soils, but that the benefits obtained are less than those obtained with formalin (thirty-eight per cent formaldehyde) applied in solution at rates of 480 gallons per acre.

In general, growth responses of Sitka spruce seedlings were much less to D.D., than were the responses to formalin. The rates of application of D.D. tested lay within the range of 150 to 600 lb. per acre.

D.D., applied at the above rates, had negligible effects on the production of seedlings, applied at least twenty-four days before sowing.

D.D. was not consistent in its weedkilling properties, and in general was inferior to formalin in this respect.

REFERENCES

EDWARDS, M. V. (1952). *The effects of partial soil sterilization with formalin on the raising of Sitka spruce and other conifer seedlings.* Forestry Commission Forest Record No. 16.

JACKS, H. (1953). Soil disinfection, XIV. Effects of chemical soil disinfectants on control of weeds. *New Zealand Sci. Comm., Sect.* A; pp. 487-91.

NEWHALL, A. G. (1946). Volatile soil fumigants for plant disease control. *Soil Science* 61: pp. 67-82.

Notes from Auchincruive. *Scot. Agric.* 33 (4): p. 218, 1954.

Table 16

MEAN HEIGHTS, TOTAL NUMBERS PER SQUARE FOOT AND WEEDING TIMES IN MINUTES PER SQUARE YARD OF 1+0 SITKA SPRUCE RAISED ON SHELL D.D.- AND ON FORMALIN-TREATED SOILS IN 1950

Treatment	Mean Heights in inches					Total Numbers per sq. ft.					Weeding times per sq. yd. in mins.*		
	Inchna-cardoch	Newton	Tulli-allan	Benmore	Fleet	Inchna-cardoch	Newton	Tulli-allan	Benmore	Fleet	Inchna-cardoch	Benmore	Fleet
D.D. (average of the three levels shown below) ...	0.62	0.61	1.02	0.58	0.84	90	46	32	77	65	6.0	8.5	8.8
Formalin	0.72	0.85	0.92	0.68	1.43	81	58	28	82	72	3.3	6.2	8.6
Control	0.50	0.56	0.93	0.52	0.80	96	53	30	91	66	6.9	12.5	10.8
S.E. ±	0.04	0.02	0.04	0.02	0.04	3	12	4	4	2	0.3	0.5	0.5
Difference for significance 5%	0.11	0.07	Not sigt.	0.06	0.11	8	6	Not sigt.	7	7	0.8	1.5	1.4
Difference for significance ... 1%	Not sigt.	0.09	Not sigt.	0.08	0.15	11	8	Not sigt.	Not sigt.	Not sigt.	1.0	2.1	Not sigt.
D.D. at 150 lb. per ac. ...	0.64	0.60	1.00	0.57	0.84	91	50	34	83	68	6.2	9.8	9.3
D.D. at 300 lb. per ac. ...	0.62	0.62	1.03	0.58	0.81	89	46	35	82	65	6.2	8.0	9.2
D.D. at 600 lb. per ac. ...	0.63	0.60	1.03	0.58	0.86	92	42	28	67	61	5.5	7.7	8.4
S.E. ±	0.04	0.02	0.04	0.02	0.05	4	2	4	3	2	0.2	0.5	0.4
Difference for significance 5%	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	5	Not sigt.	9	Not sigt.	Not sigt.	1.4	Not sigt.
Difference for significance ... 1%	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	12	Not sigt.	Not sigt.	Not sigt.	Not sigt.

The above data are the averages for both methods of sealing and of injection.

* No data collected at Newton and Tulliallan.

MEAN HEIGHTS, TOTAL NUMBERS PER SQUARE FOOT AND WEEDING TIMES IN MINUTES PER SQUARE YARD OF 1+0 SITKA SPRUCE RAISED ON SHELL D.D.- AND ON FORMALIN-TREATED SOILS IN 1951

Table 17

Treatment	Mean Heights in inches				Total Numbers per sq. ft.				Weeding times per sq. yd. in mins.			
	Inchna-cardoch	Newton	Benmore	Fleet	Inchna-cardoch	Newton	Benmore	Fleet	Inchna-cardoch	Newton	Benmore	Fleet
D.D. (mean of three levels) ...	0.90	1.43	0.90	1.20	77	45	97	88	7.8	34.7	18.4	19.0
Formalin ...	1.09	1.34	1.44	2.22	100	39	102	110	3.3	28.3	13.6	6.7
Control	0.70	1.30	0.74	1.10	78	49	102	93	7.5	40.6	22.9	24.6
S.E. ±	0.02	0.04	0.04	0.08	6	4	4	7	0.7	0.6	1.4	1.8
Difference for significance 5%	0.06	0.12	0.13	0.24	18	Not sigt.	Not sigt.	Not sigt.	2.2	Not sigt.	4.1	5.2
Difference for significance 1%	0.08	1.16	0.18	0.33	Not sigt.	Not sigt.	Not sigt.	Not sigt.	2.9	Not sigt.	5.6	7.0
D.D. at 150 lb. per ac.	0.85	1.38	0.83	1.14	70	48	95	84	7.2	32.2	20.4	22.1
D.D. at 300 lb. per ac. ...	0.94	1.44	0.95	1.19	79	45	100	95	8.7	38.4	19.2	20.8
D.D. at 600 lb. per ac.	0.91	1.47	0.91	1.28	81	43	90	87	7.4	33.3	15.6	17.2
S.E. ±	0.02	0.04	0.04	0.08	5	4	3	6	0.7	0.5	1.3	1.6
Difference for significance 5%	0.06	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.
Difference for significance 1%	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.

The above data are averages for both spacings of injection points.

MEAN *HEIGHTS*, TOTAL NUMBERS PER SQUARE FOOT AND WEEDING TIMES IN MINUTES PER SQUARE YARD OF 1+0 SITKA SPRUCE RAISED ON SHELL D.D.- AND ON FORMALIN-TREATED SOILS IN 1952

Table 18

Treatment		Mean Heights in inches				Total Numbers per sq. yd.				Weeding Times per sq. yd. in minutes.*		
		Inchna-cardoch	Newton	Benmore	Fleet	Inchna-cardoch	Newton	Benmore	Fleet	Newton	Benmore	Fleet
D.D. at 300 lb. per ac.		1.08	0.65	1.09	1.51	70	44	76	80	4.5	14.9	9.1
D.D. at 450 lb. per ac. ...		1.14	0.66	1.18	1.52	69	39	77	80	4.4	15.6	8.1
Formalin ...		1.62	0.74	1.22	2.03	69	41	85	82	3.9	11.9	6.4
Control		0.91	0.62	1.00	1.40	74	49	86	83	4.2	10.8	7.7
S.E. ±		0.04	0.05	0.03	0.063	4	6	4	4	0.4	0.7	0.4
Difference for significance ...	5%	0.11	Not sigt.	0.08	0.185	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	2.0	1.0
	1%	0.16	Not sigt.	0.14	0.252	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	2.8	1.4

The above data are the averages for cultivated and uncultivated plots.

* No data collected at Inchnacardoch.

PRUNING OF CONIFERS BY DISBUDDING

By J. W. L. ZEHETMAYR and J. FARQUHAR

(245.14)

THE system of pruning known as 'finger disbudding' or 'bud pruning' (which is illustrated in Photograph 3) has received considerable attention in recent years. The system appears to have originated in Russia at the Kiev Forestry Research Institute. Buchholtz, reporting on this work in 1939, states that disbudding was started on eight-year-old Scots pine when five feet high. Several whorls of branches were left at the base, and the tree then had the terminal whorl of lateral buds removed annually until a clean straight length of about twenty feet was obtained. Height growth was said not to be affected, while diameter growth of the stem was increased.

The method was tested from 1940 at Petawawa Forest Experimental Station Ontario (Bickerstaff, 1945) and also at Nicolet National Forest, Wisconsin (Paul, 1946) with encouraging early results for certain species. Since then a number of experiments have been reported from the U.S.A. (Glattfelder, C.F.) Australia (Anon., 1950) and from Great Britain (Mackenzie, 1953.)

These experiments were for the most part reported in their early stages when the disbudding and formation of the pole leader was in progress, and prior to the critical phase when branches are allowed to form above the clean stem. At this time the risk of breakage is great, and in fact occurred disastrously at Petawawa (R. Faulkner, personal report). The exception is that at Tullach Ard, Perthshire, where Mackenzie disbudded for three seasons only and canopy re-formed successfully above a clear length of three to six feet.

In 1947 the Forestry Commission started an experiment to investigate the possibility of the method, and to compare it with more normal methods of pruning. After this pilot experiment (on Corsican pine) had been started successfully, a series of six more experiments was begun in 1949–50 on Scots and Corsican pines, Norway and Sitka spruces, and Douglas fir. The results of these seven experiments are now recorded after six years' work.

The earlier experiments, such as those at Petawawa, had been rather in the nature of preliminary tests to discover if disbudding was at all feasible, and generally all trees within a given area were treated. The experiments now in hand presupposed that disbudding was possible and that in practical application only selected trees would be so treated.

The objects of the experiments were:

(1) To compare the cost of finger disbudding with other pruning methods in relation to the type and quality of timber produced.

(2) To compare the height and diameter growth of trees pruned by finger disbudding with that of trees subjected to more normal pruning methods and that of unpruned controls.

(3) To observe the relative incidence of damage from birds, insects, fungi, loss of leading buds, etc., that may occur in the different treatments.

The first step was to pick uniform areas of young vigorous crops, each extending to two acres, and within them to lay out comparable plots of such a size that each contained up to twenty well-formed potential dominants, spaced at twelve to fifteen feet apart.

The following treatments were then applied:

A Control treatment, dominants untouched. The crop will be treated in a normal manner, and later brashed and thinned, probably to whatever grade is considered suitable for treatment *B*.

B Dominants to be pruned by saw in the normal manner; while the experimental plan gives a regime to be followed in pruning, this work naturally will not fall due for some years, and may be modified to conform to results emerging from earlier pruning experiments. Thinning is expected to be of the Light Crown type, to favour pruned trees.

C Disbudding. The lowest two complete whorls were allowed to develop, and finger disbudding started thereafter. These lower branches are intended to provide a 'crown' for the support of the pole-like disbudded section. Special thinning is provided for, to prevent suppression of these lower branches by trees not selected for disbudding. Later on, Crown thinning will be used, but will be of rather abnormal type since the disbudded trees will be almost isolated from the start.

D Disbudded as *C*, but with four basal whorls left to support the disbudded length.

E A knife pruning treatment outside the scope of the present report.

Once treatment is completed over the experiment as a whole, the thinning may well be altered to a heavier grade ('Heavy Crown') to give maximum increment on the selected trees in all treatments.

The layout of the experiment was in five or more randomised blocks or a five by five Latin square; up to 100 trees were used in each treatment.

The results so far may be summarised:

Method of Disbudding

Experience has shown that disbudding is most easily carried out by hand after the buds have extended, and before the growth has hardened. This gives about a month in which to carry out treatment, though the actual dates vary with species and site. In general the pines and Douglas fir have been disbudded in May, and spruces mid-May to mid-June. The optimum is probably when the side shoots are one to two inches long. In the later years the use of portable step ladders became necessary, and this may limit the height to which treatment can be carried economically.

Effect on Growth

The pilot experiment on Corsican pine at Lossie Forest, Morayshire, was carefully observed for two years prior to the laying out of the other experiments. At the end of this time it was observed that the disbudded shoots appeared to be stouter and to carry longer needles than the controls, whilst the height growth was found to be slightly greater; this gain was, however, lost by the end of the third season.

In treatment *C*, where two whorls are left at the foot, all the experiments have been assessed at the end of the third and the sixth seasons from the initial disbudding. Disbudding in treatment *D* usually commenced two years later, but the Corsican pine at Wykeham, Allerston Forest, Yorkshire, and the Sitka spruce at Kielder Forest, Northumberland, were rather large to start with, and treatments *C* and *D* were started together, some whorls being cut off *C* to reduce the number of whorls at the base. Thus treatment *C* may be regarded as a more severe regime than treatment *D*.

Table 19 DISBUDDING OF VARIOUS SPECIES—COMPARISON OF GROWTH WITH CONTROL TREES

Species	Forest and Experiment Number	Heights in Feet											Girths in Inches				
		Treatment *A*: Control			Treatment *C*: Finger disbudded 2 whorls at foot			Treatment *D*: Finger disbudded 4 whorls at foot			6-yr. Results, Standard Error and Difference for Sig. at 5%		After 6 years Treatment			Standard Error and Difference for Sig. at 5%	
		Initial	+3 yrs.	+6 yrs.	Initial	+3 yrs.	+6 yrs.	Initial	+3 yrs.	+6 yrs.	S.E.	D.S.	*A*	*C*	*D*	S.E.	D.S.
Scots pine	Mabie 1 (Kirkcudbright)	2.3	5.5	10.7	2.7	6.0	10.9	2.5	6.0	11.3	±0.45	1.5	7.2	5.4	5.7	±0.37**	1.2
	Millbuie 10 (Ross)	2.5	4.1	6.1	2.6	4.1	6.0	2.7	4.4	6.5	±0.27	0.8	—	—	—		
Corsican pine	Lossie 1 (Morayshire)	2.1	4.9	8.5	2.1	4.6	7.8	2.2	4.8	8.4	±0.16*	0.5	6.1	4.9	5.5	±0.17**	0.5
	Wykeham Allerston Forest 82 (Yorks're)	4.0	8.0	12.7	4.0	7.8	11.7	3.7	7.7	11.4	±0.39	1.2	8.9	6.6	7.4	±0.47*	1.4
Douglas fir	Mabie 2 (Kirkcudbright)	5.9	13.9		5.3 Expe	10.4 riment	t Ab	5.3 ando	11.8 ned		—	—	(6.2 (3-	4.4 year girt	5.3) hs)		
Norway spruce	The Bin 4 (Aberdeenshire)	2.5	4.2	5.9	2.5	4.0	5.5	2.5	4.4	6.3	±0.23	0.7	—	—	—		
Sitka spruce	Kielder 52 (Northumberland)	3.8	7.7	11.8	4.2	7.0	9.3	4.1	7.4	10.6	±0.50**	1.5	6.9	3.3	3.8	±0.26**	0.8

Notes:—The clean length of timber in treatment *C* equals the difference between the initial and final measurements plus the length of the shoot of the year prior to the commencement of disbudding. Thus the average clean length at Lossie is now over six feet and at Wykeham over eight feet in treatment *C*. The clean length in *D* is about 1½ to 2 feet less than in *C*.

* Significant at 5% level. ** Significant at 1% level.

Table 19 sets out the heights after three, and heights and girths after six years, for three treatments, the control and the two disbuddings. The main effects of disbudding are clear. In five cases there has been a reduction in growth either in diameter or height or in both these factors; the exceptions are the two slowest growing plantations, Scots pine at Millbuie and Norway spruce at the Bin. In all cases reductions in growth are greater in *C*, the more severe treatment.

Notes on the Various Species

Scots pine. There is no reduction of height in this species, but the experiment at Mabie shows a big loss in girth increment in disbudded plots. The slow growth at Millbuie was largely attributable to a severe sawfly attack in 1950 and 1951. The trees there are not yet large enough for girthing, but it is expected that a reduction of girth similar to that at Mabie will be found.

Disbudding in this species is generally fairly successful, the main danger appears to be that side branches take over from the leader, and by their vigorous growth may strangle it at the base so that it dies back. Epicormics generally spring from the disbudded whorl of the last year or two, but present no great problem. The loss of disbudded trees from various causes so far is about fifteen to twenty per cent.

Corsican pine. There has been a significant drop in height growth at Lossie, and of girth at both sites, while the loss of height increment at Wykeham approaches significance. Nevertheless the drop is not yet serious enough to cause doubts as to the success of the disbudding. The experiment at Lossie has suffered blasting by sea winds, particularly by the storm of January 31st, 1953, which, however, did not cause the breakages that might have been expected. The loss of disbudded stems so far is:

	C—2 whorls left	*D*—4 whorls left	
Lossie ..	50 per cent	25 per cent	Blasting and dieback
Wykeham ..	35 per cent	15 per cent	Mainly broken tips

There has been a great growth of epicormic shoots at Wykeham, so that their removal has taken as long as disbudding. Corsican pine is probably rather less suitable than Scots pine for this treatment, but many fine clean stems have been produced. The bottom whorls of branches tend to grow up around the stem to form 'candelabras', and when one branch tends to dominance it has been necessary to cut it back.

Douglas fir. Disbudding of this species has been a complete failure. This crop was making very rapid growth, shoots of four feet being quite common in the period during which treatment continued. The shoots of the weaker disbudded trees tended to twist badly, and some breakages occurred in the first year. In the second year, the loss of leaders was small, and clean lengths of up to seven feet had been obtained on certain trees, in spite of an attack by *Adelges cooleyi*, and of some frost damage. In the third and fourth years dieback of the leaders started, possibly due to autumn frost. The damage is certainly correlated with disbudding, and may be due to the vigorous lammas growth on these stems. In contrast to pines, where the needles are vigorous on the disbudded length, those of Douglas fir are rarely retained, and this lack of foliage may also be a factor in causing dieback. After five years, only fourteen trees in the *C* treatment and twenty-five in the *D* treatment, out of 100 in each, had undamaged leaders, and it became obvious that the treatment must be abandoned. Trees not disbudded in 1954 or 1955 show very little signs of forming a new crown at the top, only a few weak shoots having been produced.

Norway spruce. This species shows no significant difference in height, though there is evidently a slight reduction in growth in treatment *C*. A few trees have suffered from browning of the needles and slight dieback of the disbudded stem while *Adelges abietis* insects have caused some damage. This experiment is promising, the loss of stems being very low.

Sitka spruce. This species has also lost in height increment, and particularly in girth increment, so that the girth in treatment *C* is only half that of controls. In spite of this, many clean and straight leaders have been obtained; epicormics have been numerous on individual stems, though absent in the majority. A number of leaders have broken, the loss of stems being twenty-five per cent in treatment *C* but only ten per cent in treatment *D*. Here again side branches have tended to become dominant on some specimens.

Future Treatment

When the falling-off in growth of the disbudded stems became apparent, in about the third or fourth year, it was decided to terminate the disbudding in certain blocks of all the experiments after an eight-foot length, clear of branches, had been obtained. As a result the critical phase of branch development above the clear stem has now been reached in the more rapidly growing experiments. The remaining plots will, if possible, be disbudded to give sixteen feet of clean timber. In all cases allowance has been made for branch swelling above and below, and for cross cutting, so that eight-and-a-half feet and sixteen-and-a-half feet clear are the minimum lengths specified.

Costs

During the early years, when the leaders can be reached from the ground, the operation of disbudding is very simple, taking, for pines, between half an hour and one hour per hundred trees per annum, inclusive of walking time between trees; Sitka spruce takes rather longer.

The experiments are now at a stage, however, when ladders or other means of reaching the top become essential, and the costs will mount rapidly.

REFERENCES

ANON. Bud pruning (of *Pinus Pinaster* and *P. radiata*). *Rep. For. Timb. Bur. Aust.* 1950.

BICKERSTAFF, A. Knot-free red pine by debudding. *Silvic. Res. Note, Dom. For. Serv.* No. 76, 1945.

BUCHHOLTZ, E. A new method of raising pine timber without knots. *Forstarchiv* 15. 1939.

GLATTFELDER, C. F. Is bud pruning of forest trees practical? *Pa. For. Wat.* 2(4). 1950.

MACKENZIE, J. D. M. Disbudding Scots pine. *Scottish Forestry* 7 (1), 1953.

PAUL, B. H. Tree pruning by annual removal of lateral buds. *J. For.* 44 (7), 1946.

SEASONING BEFORE EXTRACTION: A STUDY OF ITS EFFECT ON EXTRACTION TIMES

By C. D. BEGLEY

(34)

FORESTERS have always been attracted to the idea of saving handling and transport costs by discarding as much 'waste' as possible at the earliest possible moment after a tree has been felled. In this connection, the reduction of weight by seasoning has a special appeal in that the moisture removed has no potential or actual sale value. It is true that in some circumstances volume rather than weight may be the main factor determining handling and transport costs, and that for some purposes—for example for certain forms of debarking—it may be desirable to have the timber in as 'green' a state as possible. Nevertheless, there are many felling and extraction methods currently in use, and particularly those where man-handling features prominently in the operation, where savings in weight could be reasonably expected to reduce effort and perhaps costs.

At the suggestion of the Advisory Committee on the Utilisation of Home Grown Timber, the Forestry Commission recently conducted an experiment with the object of determining whether any saving in cost would be achieved by seasoning poles in the forest prior to their extraction by hand to rack or ride. A balanced assessment of the value of seasoning in the forest would require a consideration of the disadvantages of delayed extraction, as well as the possible advantage of saving in extraction cost due to loss in weight. Accordingly studies, which are not yet complete, were undertaken to correlate time of felling, and length of seasoning period, with natural loss of bark, degrade of timber, and degree of seasoning. The experiment of which the design and results are observed below, deals only with extraction costs and seasoning. The work was carried out by the students at Gwydyr and Benmore Forester Training Schools.

Design of the Experiment

Two stands of brashed Sitka spruce, each of apparently uniform growth and due for a first thinning, were chosen, one at Gwydyr Forest, North Wales, planted in 1930, and one at Benmore Forest in Argyll, planted in 1933. Both stands were on hillsides of moderately steep slope. Measurements of the girths of dominant trees in each stand were made, and the data when analysed confirmed that growth within each stand was as uniform as it appeared to be from the purely visual assessment made when the stands were selected. Narrow racks were cut at right angles to the contour and plots measuring two chains by one chain

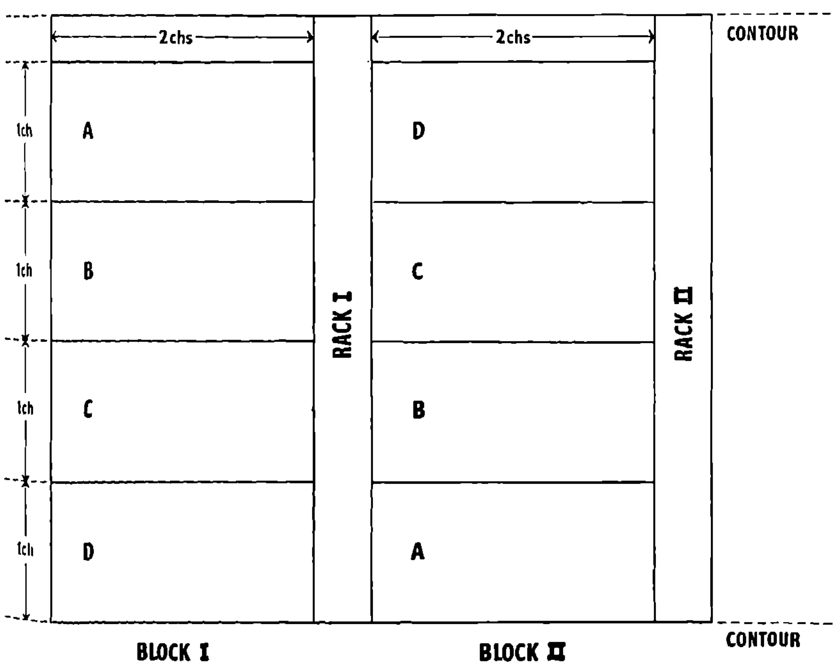


FIG. 1. Layout of experimental plots.

were laid out immediately adjacent to, and at right angles to, these racks (see Fig. 1). The long (two-chain) sides of the plots ran across the hillside, giving, for hand extraction of the poles, a maximum 'carry' of two chains, and an average carry of one chain, along the contour. A normal thinning (i.e., normal as judged by local practice) was marked in each plot.

All poles from Block I were extracted to Rack I.

All poles from Block II were extracted to Rack II.

Four different treatments were applied, there being sufficient plots to allow each treatment to be replicated.

Treatment A. Unpeeled, unseasoned. (Abbreviated Up.Us. in the tables).
Fell, trim and extract by hand to rack.

Treatment C. Unpeeled, seasoned. (Abbreviated Up.S.).
Fell, trim, place on brash to season; extract by hand to rack when seasoned.

Treatment B. Peeled, unseasoned. (Abbreviated P.Us.).
Fell, trim, peel and extract by hand to rack.

Treatment D. Peeled, seasoned. (Abbreviated P.S.).
Fell, trim, and peel; place on brash to season; extract by hand to rack when seasoned.

No work was done in *A* and *B* plots until the poles felled in *C* and *D* plots had seasoned. The extraction of both seasoned and unseasoned poles was therefore done under similar weather and other conditions and by the same men.

The following data were recorded:

(i) Over and under bark felled measure.
(ii) Over bark weight on day of felling.
(iii) Peeled weight on day of felling (*B* and *D* plots only).
(iv) Monthly sample weighings of poles lying on brash (*C* and *D* plots only).
(v) Weight on day of extraction.
(vi) Time taken in man-hours to peel (*B* and *D* plots only); lay on brash; extract by hand to rack.

Results

In spite of precautions taken, in each locality there were statistically significant differences between the volume of thinnings felled in the various treatments. The total fresh-felled over-bark weights in each plot also varied—as one would have expected even if the volumes had been precisely the same in each plot. The effect of these factors on the time taken to perform the operations carried out in the four treatments was examined, using statistical methods. However, for the sake of simplicity, it has been decided to quote only the average values arrived at as a result of this analysis, and to omit the full statistical appreciation.

Volumes Felled

The volume of thinnings removed in each treatment is given in Table 20. At Gwydyr, fifty-one trees were felled per plot, the largest trees each having a volume of just under 3.5 hoppus feet overbark; the average tree had a volume of 1.2 hoppus feet overbark. At Benmore, seventy trees per plot were felled, the largest trees having a volume of about three hoppus feet overbark; the average tree had a volume of 0.75 hoppus feet overbark.

VOLUME OF THINNINGS REMOVED IN EACH TREATMENT

Table 20 Hoppus feet, felled measure, to three inches overbark top diameter.

Treatment	Overbark		Underbark		Bark percentage*
	Average Vol. per plot	Equivalent Vol. per acre	Average Vol. per plot	Equivalent Vol. per acre	
Gwydyr					
A (Up.Us.) ...	64.6	323.0	54.6	273	15.5
B (P.Us.) ...	63.5	317.5	51.6	258	18.8
C (Up.S.) ...	58.5	292.5	51.2	256	12.5
D (P.S.)	58.2	291.0	49.8	249	14.5
Benmore					
A (Up.Us.) ...	57.6	288.0	49.2	246	14.6
B (P.U.) ...	56.8	284.0	49.5	247	12.9
C (Up.S.) ...	46.2	231.0	39.2	196	15.2
D (P.S.)	48.0	240.0	42.2	211	12.1

$$* \text{ Bark percentage} = 100 \times \frac{\text{Overbark Volume} - \text{Underbark Volume}}{\text{Overbark Volume}}$$

Weights

The fresh-felled weights of timber and volume/weight ratios are given in Table 21 for each treatment. The loss in fresh-felled weight due to peeling was almost nine per cent in both localities.

FRESH-FELLED WEIGHTS AND LOSS IN WEIGHT DUE TO PEELING

Table 21

Treatment	Before Peeling			After Peeling			Loss in weight %*
	Average wt. per plot tons	Equivalent wt. per acre tons	Hoppus ft. per ton (overbark)	Average wt. per plot tons	Equivalent wt. per acre tons	Hoppus ft. per ton (under-bark)	
Gwydyr							
A (Up.Us.)	2.29	11.45	28.21	—	—	—	—
B (P.Us.)	2.31	11.55	27.49	2.07	10.35	24.93	10.39
C (Up.S.)	2.14	10.70	27.34	—	—	—	—
D (P.S.)	2.13	10.65	27.32	1.97	9.85	25.28	7.51
Mean (*A, B, C, D*)	2.22	11.09	27.59	2.02 (B.D.)	10.10	25.10	8.95
Benmore							
A (Up.Us.)	2.06	10.30	27.96	—	—	—	—
B (P.Us.)	2.01	10.05	28.26	1.84	9.20	26.9	8.46
C (Up.S.)	1.76	8.80	26.25	—	—	—	—
D (P.S.)	1.87	9.35	25.67	1.70	8.50	24.8	9.09
Mean (*A, B, C, D*)	1.93	9.63	27.04	1.77 (B.D.)	8.85	25.85	8.77

$$* \text{ Percentage loss in weight} = 100 \times \frac{\text{Overbark weight} - \text{Underbark weight}}{\text{Overbark weight}}$$

Loss of Weight due to Seasoning

In the *C* and *D* treatments at Benmore, loss in weight due to seasoning was twenty-two per cent of the fresh-felled overbark weight for unpeeled poles (*C*); while peeled poles (*D*) lost (including loss in weight due to removal of bark) forty-two per cent of their fresh-felled overbark weight. At Gwydyr, loss in weight due to seasoning amounted to thirteen per cent of the fresh-felled overbark weight in the case of unpeeled poles (*C*), while peeled poles (*D*) lost (including loss in weight due to removal of bark) forty-two per cent of their fresh-felled overbark weight. These results are given in Table 22 and in each case the loss is expressed as a percentage of the overbark fresh-felled weight. If the loss of weight due to removal of bark is excluded, then the peeled poles were reduced in weight by seasoning—by thirty-six per cent at Benmore and thirty-seven per cent at Gwydyr.

WEIGHT OF SEASONED POLES AND LOSS OF WEIGHT DUE TO SEASONING

Table 22 Per Plot

Treatment	Fresh-felled weight tons	Seasoned weight tons	Loss percentage in weight	Hoppus feet per ton
Gwydyr				
C (Up.S.)	2.14 O.B.	1.87 O.B.	12.6*	31.3 O.B.
D (P.S.)	2.13 O.B.	1.24 U.B.	41.7†	40.1 U.B.
Benmore				
C (Up.S.)	1.76 O.B.	1.38 O.B.	21.6*	33.5 O.B.
D (P.S.)	1.87 O.B.	1.09 U.B.	41.7†	38.7 U.B.

* Percentage loss in weight =

$$100 \times \frac{\text{Overbark fresh-felled weight} - \text{Overbark seasoned weight}}{\text{Overbark fresh-felled weight}}$$

† Percentage loss in weight =

$$100 \times \frac{\text{Overbark fresh-felled weight} - \text{Underbark seasoned weight}}{\text{Overbark fresh-felled weight}}$$

Effect of Treatments on Time Taken to Perform Various Jobs

Peeling. There were no significant differences between the peeling times for the various treatments. For the conditions under which this experiment was conducted this result showed:

(1) That poles peeled immediately after felling (*D* and *B* treatments) were peeled in the same time, although the two groups of poles *D* and *B* were felled in the summer and winter, respectively.

(2) That with poles felled in the winter, peeling was not easier or more difficult five months later (*C* treatment) than immediately after felling (*D* treatment).

(3) That poles felled in summer and peeled immediately after felling (*B* treatment) were not easier or more difficult to peel than poles which had been felled five months previously (*C* treatment).

The time of felling, and the delay between felling and peeling, did not therefore affect the ease of peeling sufficiently (if at all) to appear in these results. It is not shown what effect delay in peeling would have had if felling and peeling had been (i) at different intervals, or (ii) at different seasons, than those discussed here.

Laying Poles on Brash. The operation of laying poles on brash in the *C* and *D* treatments took on an average about one-and-a-half hours per plot at Gwydyr, and three hours per plot at Benmore. The greatly increased time at Benmore may be accounted for by the greater difficulty in collecting brash, and by the somewhat steeper and rougher slopes encountered in the experimental area.

Extraction by Hand to Rack. The time taken to extract the unseasoned poles of treatments *A* and *B*, by hand, to the rack was significantly greater, both at Benmore and Gwydyr, than the times taken to extract the seasoned poles of *C* and *D* treatments, respectively. The savings in extraction time due to seasoning the poles were, however, insufficient to cover the extra time required to lay the poles on brash to season. This is demonstrated in Table 23.

Table 23 — Man-hours

Treatment	Average per plot			Average per acre		
	Extraction (i)	Laying poles on Brash (ii)	Total (i) and (ii)	Extraction (i)	Laying poles on Brash (ii)	Total (i) and (ii)
Gwydyr						
A (Up.Us.) ...	3.08	—	3.08	15.40	—	15.40
C (Up.S.) ...	2.48	1.35	3.83	12.40	6.75	19.15
B (P.Us.) ...	3.08	—	3.08	15.40	—	15.40
D (P.S.)	1.86	1.57	3.43	9.30	7.85	17.15
Benmore						
A (Up.Us.) ...	2.39	—	2.39	11.95	—	11.95
C (Up.S.) ...	1.31	3.25	4.56	6.55	16.25	22.80
B (P.Us.) ...	2.12	—	2.12	10.60	—	10.60
D (P.S.)	1.12	2.57	3.69	5.60	12.85	18.45

Conclusions

The seasoning of poles on brash in the forest, prior to extraction by hand to rack or rideside, is not likely to lead to a saving in total costs, i.e., savings in extraction times are likely to be offset or exceeded by the extra time taken to collect brash and place poles upon it to season.

Discussion

Practical experience suggests that it is not necessary to go to the trouble of placing poles on specially collected piles of brash to season, and that a comparable rate of seasoning is achieved by merely leaving the poles where they happen to fall, or at most raising the ends on stumps or tops. An exception is made in the case of poles which have fallen in hollows in the ground where water accumulates. Such poles would normally be raised or moved to a drier location. It is hoped to repeat the experiment in order to find out whether there is any saving in total time (and, therefore, cost) when, prior to extraction, poles are seasoned at stump but not piled on brash.

MOISTURE CONTENT OF FRESH-FELLED HARDWOODS

By C. D. BEGLEY and J. N. R. JEFFERS

(812.211)

THIS paper summarises data on the moisture content of fresh-felled hardwood timber, which have been collected in the course of experiments on the production and utilisation of hardwoods.

The data come from three main sources:

(1) Samples collected specifically to estimate the moisture content of timber of a number of hardwood species, in the course of an investigation into the use of hardwood for pulping. These samples were collected from two sites in South-west England; they also give information on the effect of size of tree and position within the tree on moisture content.

(2) Samples collected to estimate the moisture content of oak and other hardwoods in the pole stage, as part of an experiment on the effect of poisoning by sodium arsenite on bark peeling. Samples from the unpoisoned trees give the moisture contents of oak at several times of the year, and of mixed hardwoods in September.

(3) Samples from other experiments in which moisture content was a character of secondary importance.

Throughout this paper, the moisture content of timber has been calculated from the formula:

$$\text{Moisture content (per cent)} = \frac{\text{Wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

1. Main Experiment

The average moisture contents of timber of trees of given species are shown in Table 24.

OVERALL MOISTURE CONTENTS

Table 24

Species		Average moisture content (percentage)	
Oak		77.1	±5.31
Beech...		86.5	
Birch		77.3	
Sweet Chestnut ...		96.0	
Ash		47.1	
Sycamore		83.0	
Elm		75.1	
Alder...		105.9	
Willow		83.0	
Poplar		136.3	
Differences for significance	5%	15.7	
	1%	21.5	

The overall moisture content of poplar timber was very significantly greater than that for any other species, and the overall moisture content for ash timber was very much lower than that for any other species. The moisture contents of timber of the other species did not differ significantly, though they were rather higher for alder and sweet chestnut than for oak, beech, birch, sycamore, elm and willow.

Table 25 gives the average moisture content (over all species) of timber of two sizes, and Table 26 gives the average moisture contents for these two sizes for each species.

MOISTURE CONTENT IN RELATION TO SIZE: ALL SPECIES

Table 25

Timber of sizes		Average moisture content (percentage)	
Trees of 6 inches and over quarter-girth, over-bark, at breast height		86.6	± 2.38
Trees under 6 inches quarter-girth, over-bark, at breast height		86.9	
Differences for significance	5%	7.0	
	1%	9.6	

MOISTURE CONTENT IN RELATION TO SIZE: BY SPECIES

Table 26

Species	Average moisture content, as percentage, for trees :	
	Six inches and over in quarter-girth, over-bark, at breast height	Under six inches quarter-girth, over-bark, at breast height
Oak	74.5	79.7
Beech	84.1	89.0
Birch ...	76.4	78.2
Sweet Chestnut	94.2	97.8
Ash ...	46.9	47.3
Sycamore ...	78.6	87.3
Elm ...	81.9	68.4
Alder	107.0	104.9
Willow	80.2	85.7
Poplar	141.9	130.7

There was no significant difference between the average moisture content of trees of six inches breast-height quarter-girth (over bark) and over, and trees under that limit. There was also no significant interaction between the size of tree, and the species, on the moisture content.

Table 27 gives the average moisture content at different positions in the trees, and Table 28 gives the average moisture content at the different positions for each species.

MOISTURE CONTENT IN RELATION TO POSITION IN TREE: ALL SPECIES

Table 27

Position in tree		Average moisture content (percentage)
Butts		90.6 ⎫
Middles ...		86.1 ⎬ ±1.93
Tops		83.6 ⎭
Differences for significance	5%	5.5
	1%	7.3

MOISTURE CONTENT IN RELATION TO POSITION IN TREE: BY SPECIES

Table 28

Species	Average moisture content, percentage at:		
	Butt	Middle	Top
Oak	81.0	76.3	74.2
Beech ...	80.4	90.0	89.4
Birch ...	69.5	78.7	83.7
Sweet Chestnut ...	117.6	88.7	81.6
Ash ...	51.4	45.3	44.6
Sycamore	82.3	85.5	81.1
Elm ...	83.2	77.8	64.4
Alder ...	94.6	110.5	112.8
Willow ...	84.0	82.7	82.2
Poplar ...	161.7	125.5	121.8

Although there was a significant trend towards higher moisture contents at the butts of the trees than at the middles or the tops, only for poplar and sweet chestnut were the moisture contents significantly higher at the butts than at the other positions. For alder and beech the moisture content at the butt was significantly or appreciably lower than at the other positions.

Table 29 gives the average moisture content of branchwood of different species.

MOISTURE CONTENT OF BRANCHWOOD IN RELATION TO SIZE: BY SPECIES

Table 29

Species	Average moisture content percentage	
	Branches of 6 inches quarter-girth, and over (over-bark)	Branches between 3½ and 6 inches quarter-girth (over-bark)
Oak	65.9	66.4
Beech...	86.2	85.0
Birch	—	70.0
Sweet Chestnut ...	—	42.2
Ash	48.7	47.0
Sycamore	80.5	74.4
Elm	81.9	65.3
Alder...	97.5	103.9
Willow	86.2	81.5
Poplar	—	108.3
Hornbeam	68.0	77.5
(all species)	± 3.08	± 2.94
Differences for significance 5%	9.3	8.5
Differences for significance 1%	13.0	11.5

There were, again, significant differences between the average moisture contents of the branchwood of the different species, but no significant difference in moisture content between branchwood of different sizes.

The moisture contents of the alder and poplar branchwood were significantly greater than those for the other species; the moisture contents of ash and sweet chestnut were significantly lower than those for the other species. The drop in moisture contents for the branchwood, compared with those for timber, in the case of oak, sweet chestnut, and poplar, is of some interest.

There were no significant interactions between positions and size classes.

The data of Tables 24 to 29 therefore suggest that there are differences between the moisture contents of trees of different species, but that the differences in moisture content between trees of different sizes are of little importance. In general, however, the moisture content of the branchwood differs from that of the timber.

The main interest lies, not in the difference between species, size classes, and positions in the tree, but in the *possibility of estimating the probability of given moisture contents for a given species.* The major variability in moisture content would appear to be a tree-to-tree variation, and this is unlikely to be greatly reduced by limiting the collection of samples to particular sizes of tree, or to particular positions in the tree. The variability is a natural phenomenon, as deserving of interest as the average moisture content. Although intensive sampling will enable estimates of the average moisture content *for that sample* to be made with some precision, sampling in this way will give little more information about the range of naturally occurring moisture contents in individual trees.

Table 30, therefore, gives not only the average moisture content of timber for each species, but also the ranges of moisture contents within which will lie approximately ninety-five per cent of all trees, and approximately ninety-nine per cent of all trees. These ranges are called the *fiducial limits.*

MOISTURE CONTENT OF TIMBER, BY SPECIES, WITH FIDUCIAL LIMITS

Table 30 Moisture content (percentage)*

Species	Average	95% fiducial limits	99% fiducial limits
Oak	77.1	67.5— 86.7	63.5— 90.7
Beech	86.5	76.9— 96.1	72.9—100.1
Birch	77.3	67.7— 86.9	63.7— 90.9
Sweet Chestnut	96.0	85.9—106.1	80.2—111.8
Ash ...	47.1	41.2— 53.0	33.4— 60.8
Sycamore ...	83.0	73.4— 92.6	69.4— 96.6
Elm ...	75.1	65.5— 84.7	61.5— 88.7
Alder	105.9	95.8—116.0	90.1—121.7
Willow	83.0	73.4— 92.6	69.4— 96.6
Poplar	136.3	95.2—177.4	41.6—231.0

* Based on three samples per tree.

The moisture content of hornbeam was also found for one site. The average moisture content per tree was 73.7 per cent, with a standard deviation of 2.40 per cent.

Table 31 gives the average moisture content of branchwood for each species, and also the ranges of moisture contents within which will lie approximately ninety-five per cent of all trees, and approximately ninety-nine per cent of all trees.

MOISTURE CONTENT OF BRANCHWOOD, BY SPECIES, WITH FIDUCIAL LIMITS

Table 31 Moisture content (percentage)*

Species	Average	95% fiducial limits	99% fiducial limits
Oak	66.1	52.8— 79.4	50.9— 81.3
Beech	85.6	72.3— 98.9	67.8—103.4
Birch	70.0	56.7— 83.3	52.2— 87.8
Sweet Chestnut	42.2	34.8— 49.6	31.5— 52.9
Ash ...	47.9	40.5— 55.3	37.2— 58.6
Sycamore ...	77.4	64.1— 90.7	59.6— 95.2
Elm ...	70.8	57.5— 84.1	53.0— 88.6
Alder	101.8	91.8—111.8	86.6—117.0
Willow	82.5	69.2— 95.8	64.7—100.3
Poplar	108.3	98.3—118.3	93.1—123.5
Hornbeam ...	74.3	61.0— 87.6	56.5— 92.1

* Based on one sample per tree.

These data are shown graphically in Figure 2 below.

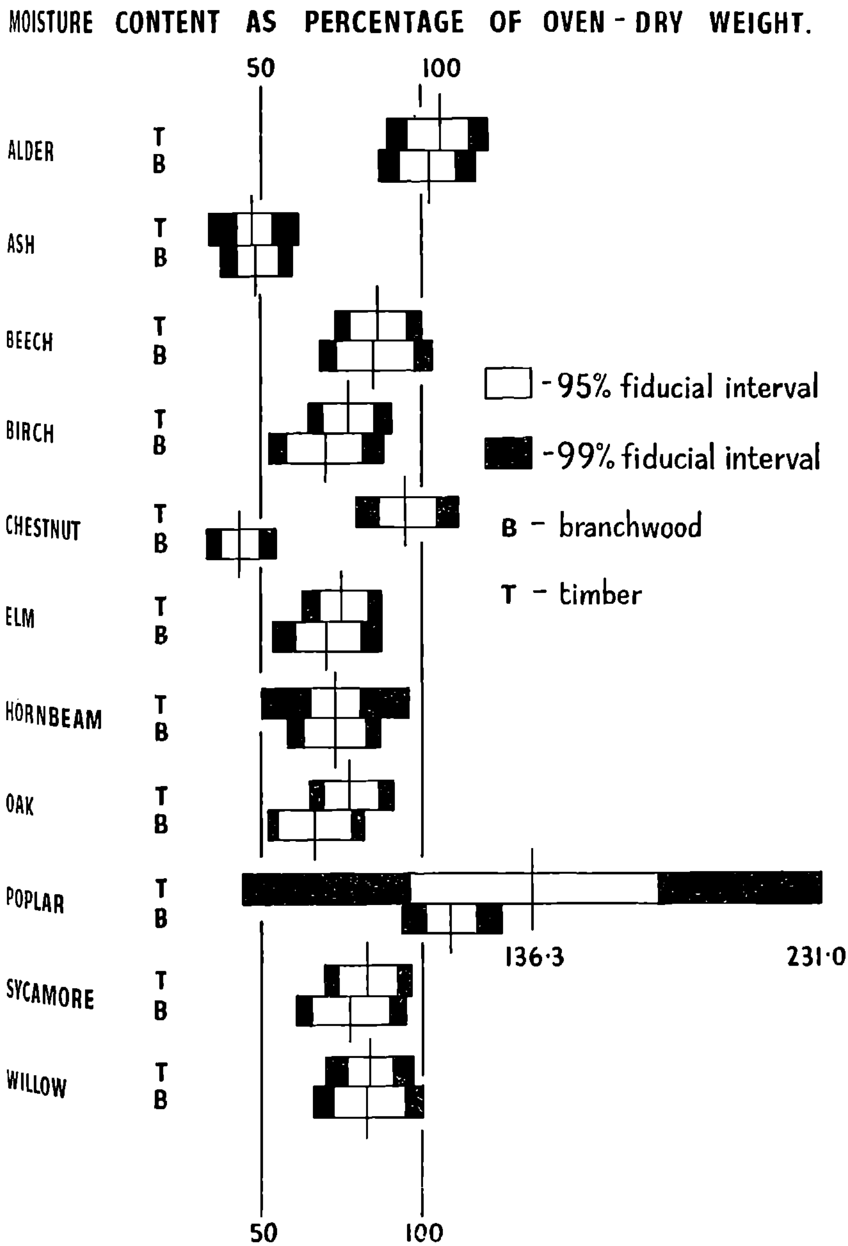


FIG. 2. Fresh-felled moisture content of timber and branchwood of eleven hardwood trees.

2. Pole Stage Hardwoods

Table 32 gives the moisture content of oak poles in four different months.

MOISTURE CONTENT OF OAK POLES, BY MONTHS

Table 32 Moisture content (percentage)

Month	Average ± S.E.	95% fiducial limits
June	81.5±7.76	41.4—121.6
July	84.2±4.14	62.9—105.5
August ...	75.6±5.23	48.6—102.6
October	85.6±5.82	55.6—115.6

There were no significant differences between the moisture contents of the oak poles at the different months. These moisture contents were very similar to those found in the main experiment, but, because the data were derived from fewer samples, the fiducial limits are rather wider.

Table 33 gives the moisture contents of other hardwoods in the pole stage.

MOISTURE CONTENT FOR VARIOUS SPECIES OF HARDWOOD POLES

Table 33 Moisture content (percentage)

Species	Average±S.E.	95% fiducial limits
Ash	48.4±3.04	34.6— 62.2
Beech... ...	77.9±4.90	55.7—100.1
Birch ...	88.4±4.88	66.3—110.5
Chestnut ...	105.2±6.41	76.2—134.2
Elm	63.0±6.56	33.3— 92.7
Sycamore	54.3±2.82	41.5— 67.1

These moisture contents agree well with those found in the main experiment, except for sycamore where the moisture content was somewhat lower. The fiducial limits were again a little wider.

3. Data from Miscellaneous Experiments

Samples were taken from fresh-felled oak scrub in Somerset. The average moisture content of the timber was 81.6 per cent, and that of the cordwood was 88.0 per cent. The cordwood, however, is not comparable with the branchwood in the previous tables, as it consisted mainly of split lengths of timber too crooked for anything but firewood.

In sweet chestnut coppice, the moisture content of fresh-felled samples ranged from 94.8 per cent to 108.9 per cent. These moisture contents are closely comparable to those found for timber in the main experiment.

In hazel coppice, the moisture content of fresh-felled samples from twenty-year-old, or older, coppice was about 80 per cent.

EXPERIMENTS IN THE POISONING OF STANDING TREES TO FACILITATE BARK PEELING OF FELLED LOGS

By G. D. HOLMES

(323.5)

DURING the period 1951 to 1953, a series of trials was carried out of chemical treatments applied to pole crops, with the object of killing selected trees and loosening the bark. This application of poisons to living trees, to extend and fix easy peeling characteristics, has been the subject of extensive experiment in the United States and Canada during the past five years. There is considerable economic justification for such work, owing to the high cost of peeling, particularly when done outside the normal sap peeling season in the spring.

It is thought that this technique may have a place in British forestry for application to trees scheduled for removal in thinning operations, in particular those thinnings destined for disposal as peeled pitwood or pulpwood. Present peeling costs for this class of produce are high, being of the order of sixpence per cubic foot. Accordingly, trials have been carried out on a range of conifer species, including Sitka spruce, Japanese larch, Corsican pine and Douglas fir, in order to examine the effects of chemical treatment on wood weight and ease of bark peeling.

Other trials have also been made on hardwood species.

American and Canadian evidence indicates that if a tree can be killed rapidly by application of a poison during the period of maximum sap flow in the late spring, the cambium can be fixed in a thin-walled condition. This results in reduced peeling costs, and easy peeling at any time of the year, and also an appreciable drying out of the tree which may significantly affect handling and extraction costs. In 1942, an American patent was issued for a technique of chemical bark peeling by the Armstrong Forest Company of Pennsylvania. This Company later withdrew their patent and released the technique for general use. This, and later works (1, 3, 6, 10 and 11), resulted in the development of a generally successful simple field technique using sodium arsenite as the poison. The technique involves application of the poison to a girdle cut near the base of the tree at the period of maximum sap flow in late May to early June. The main effects are said to be:

(1) Easier peeling;
(2) Extension of the normal eight to ten weeks sap peeling season to allow easy peeling at all seasons;
(3) Reduction of wood loss in peeling;
(4) Reduction of wood weight by partial seasoning on stump;
(5) Reduction of resin flow, easing handling of produce.

The first trials carried out by the Forestry Commission were started in 1951, using the compound and the technique indicated by American work, in order to test its effectiveness under British conditions, and also to examine alternative chemicals and methods of application. The crops selected for the first trials were as follows:

Species	*Age in Years*	*Average girth at Breast Height inches*	*Location*
Sitka spruce	23	15	Gwydyr Forest, N. Wales
Japanese larch	21	18½	Gwydyr Forest, N. Wales
Corsican pine	25	16	Thetford Forest, E. Anglia
Douglas fir	24	16	Alice Holt Forest, Hants

The procedure was to select a uniform pole crop scheduled for thinning, and to apply the treatment under test to randomly selected trees covering the range of girth classes present. For all four species examined, the poisoning was done in late spring with the intention of carrying out bark peeling tests in the autumn or winter of the same year, or in the spring of the following year.

Treatments and Methods

The main trials were concerned only with sodium arsenite, applied in aqueous solution containing the equivalent of four lb. arsenious oxide (As_2O_3), per gallon of water. For this compound, two methods of application were tested, as follows:

(1) Arsenite solution applied by means of a paint brush to the sapwood exposed after removal of a girdle of bark four to six inches wide around the stem at three feet above ground level. ('Band' girdling).

(2) Arsenite solution applied by pouring it from a small spouted can into the lip of a 'frill' girdle made around the tree at three feet above ground level. ('Frill' girdling).

Ammonium sulphamate in forty per cent aqueous solution was tested in subsidiary trials. This compound was compared with sodium arsenite in applications by several methods as follows:

(1) Application to band and frill girdles as dry crystals.

(2) Application as solution to 1, 2, 3 or 4, half-inch auger holes bored into the stem, sloping downwards towards the pith for a depth of three inches.

(3) Application as dry crystals to 'cups' cut into the stem by means of a small hand axe, to a depth of one and a half inches into the sapwood.

(4) Application to a narrow groove made completely round the stem by means of a timber scribe to a depth of a quarter of an inch into the sapwood. In this case the treatment was applied in the form of a starch paste containing forty per cent of the toxic chemical.

Observation and Results of Trials

Effects during the Summer Following Treatment

Some observations on early results in the first trials were given in 1952 (9). It was noticed that the species differed considerably in their response to the various treatments, but that generally sodium arsenite was much more effective than ammonium sulphamate, Sitka spruce and Japanese larch were affected rapidly, and showed extensive wilting and browning of the foliage within seven days of treatment. Japanese larch was highly sensitive, and several trees receiving arsenic to 'band' girdles showed complete browning of the crowns within forty-eight hours of the treatment. For both these species, arsenic applied to 'band' girdles resulted in complete browning of the foliage within three to four weeks. Treatment of 'frill' girdles, bore holes, cups, or a sapwood groove, resulted in a slower reaction, but with all methods arsenite solution resulted in a more rapid kill than did ammonium sulphamate.

The rate of translocation of the poison was found to vary somewhat with individual stems, and generally it was the most vigorous and open trees that were affected most rapidly.

Corsican pine was found less easy to kill, but arsenic applied to band girdles proved the best treatment. In this species only slight browning of the foliage was apparent within seven days of the treatment and the crowns of arsenic-treated trees were not completely dead until six months after treatment.

Douglas fir was found to show symptoms of poisoning only very slowly; an observation also made by De Moisy (7). The earliest symptoms appeared some three weeks after treatment with arsenic, and took the form of a discoloration and browning of the tips of needles, mainly in the upper part of the crown. The effects were most pronounced on one-year-old needles, which were shed extensively five to six weeks after treatment. New needles, on shoots which had developed shortly after treatment, appeared entirely unaffected until some two months after treatment; then extensive tip browning occurred.

These observations on the nature, and rate of onset, of damage to the foliage and crowns of the trees, enabled an early estimation of the relative rates at which the compounds were translocated to the crown in toxic quantities. For all species, the first symptoms were the discoloration and browning of the needles, usually starting at the top of the crown and extending downwards. In the most effective treatments, this stage was followed by complete browning and death of the crown, and extensive shedding of needles. At each of the three sites, several trees were girdled by the various methods *without* chemical application, and without exception trees treated in this way retained a healthy colour and continued growth throughout the season, although such treatment would probably prove fatal by the following year.

As noted, Corsican pine, and particularly Douglas fir, were slower to show these symptoms than either Japanese larch or Sitka spruce. It now appears that the rate at which the tree crown is killed provides a useful indication of the likely effectiveness of the treatment in bark loosening; the trees killed most rapidly having the most thoroughly loosened bark. The rate of translocation of the poison, as judged by the rate of death of the crown, appears to be influenced by many factors, and the following have been found important during the course of these trials:

(1) *Species.* Both Douglas fir and Corsican pine were slow to show effects in the crown; and it seems possible that this may be influenced by the profuse flow of resin occurring after girdling, which may prevent translocation of some part of the poison applied.

(2) *Sap flow.* The most rapid response was shown by those trees showing vigorous shoot development and abundant sap bleeding at the time girdles were cut. 'Dry' trees, and trees showing retarded flushing, responded more slowly.

(3) *Type of girdle.* The most rapid effects were obtained with the band type of girdle. All other methods tested, including frills, bore holes, shallow cups, and groove girdling, involved cuts into the sapwood of varying depth, and translocation of toxic amounts of chemical to the crown was much slower.

(4) *Chemical applied.* Application of chemicals in crystalline form was much less effective than application in solution, and sodium arsenite in solution took effect more quickly than ammonium sulphamate.

Examination of the trees in November, seven months after treatment, showed that most of the treated trees of Sitka spruce, Japanese larch and Corsican pine were dead, irrespective of the method of girdling or whether arsenite or sulphamate was used as the toxic chemical. The only exceptions were those trees to which the chemicals had been applied to bore holes or cups, made at intervals around the stem. With these treatments, many trees showed live strips of bark extending up the tree between the points at which the poison was applied, indicating that little lateral movement of the poison had occurred.

The condition of Douglas fir was quite unlike that of the other species examined, as none of the treatments had killed the trees completely. The only lethal method was an extreme application of sodium arsenite. This involved the maintenance of a large volume of the solution in permanent contact with the exposed sapwood of a band girdle, by means of a rubber sleeve wired tightly at the base to form a reservoir around the tree.

The Effects of Treatment on Felling and Bark Peeling

The test trees of Japanese larch and Sitka spruce were felled in the autumn, and those of Corsican pine in the spring, following girdling, for assessment of the effect of treatments on peeling characteristics. Inspection of treated trees shortly before felling showed that there had been little movement of poison downwards from the point of application, except in the case of Japanese larch which showed death of the stem to ground level with the most effective treatments. Douglas fir, spruce and pine on the other hand were unaffected below the point of application, and remained alive with no loosening of the bark, even though the stem above the girdle was dead, with considerable bark loosening. When the trees came to be felled it was found that a living and 'green' butt, found in all treatments with spruce and pine, was a slight advantage in easing felling and sawing, as compared with Japanese larch, which was dry and hard below the girdle. Apart from larch, there was no difference in ease of felling between poisoned and unpoisoned trees.

Snedding, or the trimming of branchwood, after felling, was more time-consuming for poisoned trees, because the stem and branches had dried out considerably, making cutting more difficult. It was estimated that snedding required about thirty per cent longer to complete than for untreated trees.

Many of the poisoned stems showed extensive vertical bark cracking, and also much raising of the bark from the wood. Subsequent peeling tests showed considerable differences between the various treatments, in the extent of such bark loosening. For all species, sodium arsenite applied in solution to a band girdle gave best results. The cambium was killed rapidly and completely, so that by the end of the first season the bark was dry and loose. Application of the solution to frill girdles, bore holes or cups, led to the cambium being killed more slowly, and peeling of sample logs revealed numerous patches and strips of tight bark which made them more difficult to peel than untreated trees.

Trees to which poison solution had been added in half-inch auger holes or cups at the base showed various effects. Trees with only one or two bore holes or cups were alive, showing strips of live tissue with firm bark, ascending at a slight angle up the tree, whereas those with three or four bore holes had dead, loose bark all round. The same phenomenon was observed earlier in the season in closely spaced bore holes and cup treatments. The cambium was killed in a strip above the point at which the poison was applied, this strip ascending in a gradual spiral up the stem. The live strips in between remained alive for some time, the cambium still continuing to produce secondary wood, resulting in slight ridges and hollows up the stem, corresponding with the strips of living and dead cambium.

Application of arsenic solution in the form of a paste to a groove in the sapwood did not loosen the bark as effectively as the band treatment. Ammonium sulphamate was generally less effective and slower acting than arsenic, and patches of tight bark were still present on the treated trees by the end of the season.

Careful timing of hand peeling of Sitka spruce and Japanese larch in late summer showed that felled logs from trees poisoned with arsenic could be peeled in twenty-five to thirty-five per cent less time than normal untreated trees. In Corsican pine the peeling tests were done in the spring following treatment. Sap was well up and untreated trees peeled easily, but even so the arsenic-treated poles were peeled in five to ten per cent less time. Much of the peeling time on poisoned logs of pine was spent on the top three- or five-foot section of the logs, where the bark was found to be much tighter than the lower and mid-sections, from which the bark fell off very readily. Tests on trees that had received poison to frills, bore holes, cups or grooves, showed that, owing to the presence of patches or strips of tight bark, peeling was no easier, and in most cases considerably more difficult, than peeling untreated stems. It was also found that trees girdled by the various methods used, but without any poison application, peeled no more readily than completely normal stems.

It was apparent from these trials that application of forty per cent sodium arsenite to band girdles, cut in the period of sap flow in late spring, made possible easy peeling if the trees were later felled at any time from the first autumn following treatment. The peeling is slightly easier than that for untreated trees felled at the spring 'sap-peeling' time, but there is considerable advantage in that it can be done at any time of the year. With Douglas fir, all treatments failed to loosen the bark; and for this species poisoned trees were found more difficult to peel than normal stems.

Changes in Weight per Unit Volume of Wood, and the Effect of Treatment on Ease of Extraction

The effect of treatment on the rate of drying, and the weight of poles, was determined for wood samples taken at intervals along the length of a number of randomly selected trees of each species. Samples were taken from three positions on each stem, as follows:

(1) Below girdle—mid-way between ground level and girdle, i.e., about eighteen inches above ground.
(2) Mid-point—half-way from stump level to timber limit.
(3) Top—at timber limit.

The results are summarised in Table 34.

EFFECT OF POISONING TREES IN SPRING, WITH FORTY PER CENT SODIUM ARSENITE, ON THEIR VOLUME PER UNIT WEIGHT AFTER FELLING NEXT AUTUMN

Table 34

Species	Treatment	Volume (hoppus cubic feet), freshly-felled timber per ton weight		
		Below Girdle	Mid Point	Top
Sitka spruce	No treatment	28.1	29.0	28.5
	Band girdle	30.9	60.2	55.5
	Frill girdle	34.0	56.3	53.9
Japanese larch	No treatment	30.2	29.0	29.0
	Band girdle	33.1	50.2	57.3
	Frill girdle	36.9	50.4	52.9
Corsican pine	No treatment	—	28.0	28.0
	Band girdle	—	49.0	59.0
	Frill girdle	—	39.0	59.0

Note:—Girdled, unpoisoned trees showed no appreciable loss of weight during the first season.

These figures show the loss of weight per unit volume of wood amounted to forty to fifty per cent of the original weight, in the case of spruce and larch; and thirty to fifty per cent in the case of Corsican pine. This weight loss is largely accounted for by the loss of moisture as the tree died. It was considerable, and greatly eased the handling and extraction of treated stems. It was not possible to make a reliable estimate of the implications of such a weight reduction for extraction on a large scale; however, timings made during the trial indicated that a given volume of treated produce could be extracted by hand in thirty to forty per cent fewer man-hours than the same volume of untreated material. The weight loss was so great that it was frequently possible for one man to handle a log normally requiring two men to lift. Trees treated with ammonium sulphamate also showed considerable loss of weight, although this compound was not successful as a de-barking treatment. A small, but important, practical point was the absence of resin on treated stems, which made handling cleaner and easier.

Incidence of Attack by Fungi and Insects on Poisoned Trees

Since, to secure ease of peeling, poisoned trees must be left standing in the forest for some months after death, there appears to be a danger of a build-up of insect or fungal pests before these trees are felled. This danger would probably be greater the larger the number of trees, and the larger the size of area treated. In the trial areas a limited development of blue stain fungi took place on the sapwood of treated trees. Fungal growth was apparent mainly on Japanese larch, which showed profuse development of ascomycetes (*Dermatea* species), which appears to be mainly saprophytic. *Trichoscyphella hahniana* (= *Dasycypha calycina*) produced numerous fructifications on the dead branches of treated larch; no such development was observed on control trees or any other trees in the area.

Little unusual insect activity was noted on treated trees. Some bark beetle activity was evident, and *Hylurgops palliatus* and *Rhizophagus* species were found to occur sporadically in the butts of treated pine. It seems possible that, with arsenic-treated trees, the toxin present in the cambium and bark may prevent serious insect attack for some time.

Hazards Associated with the Use of Arsenic

Sodium arsenite has given the most promising result of the compounds tested, and it is well to consider some of the risks connected with its use. The chemical is poisonous if taken internally, and caution is necessary to avoid getting the solution on the skin or in the eyes, mouth or nose, as it may cause irritation. However, if the proper precautions are taken, and the person handling the solution is protected by rubber gloves and waterproof clothing, the risks are small. The danger to animals and birds in treated areas appears slight, and no cases of poisoning have been seen. The main risk would be to animals licking the treated girdles, but the poison is removed rapidly in the sap stream after application, and the girdles are dry within two or three hours after treatment. Cook (4) reports that with extensive applications in the United States there has been no evidence that poison used to treat trees has been injurious to game; this observation was based on trials in areas well-stocked with deer and smaller forest animals.

The quantity and distribution of arsenic in trees treated with forty per cent sodium arsenite solution was examined for Sitka spruce, on samples taken at the time the test trees were felled in the autumn. The initial application in the case of the band girdle treatment amounted to approximately twenty millilitres of forty per cent solution per tree, which is equivalent to eight grams of arsenious oxide (As_2O_3) per tree. This, of course, varied a good deal according to the size of the tree, but it provides an approximation of the amount applied. Examination of the distribution of arsenic through the tree showed a concentration of thirty parts per million As_2O_3 on wood dry weight in the lower part of the stem, decreasing to 0 to 10 parts per million near timber limit. This was based on analysis of samples taken from the outer quarter-inch of sapwood, there being little movement of the poison into the centre of the tree. There was a considerable concentration of arsenic in the needles, and analysis of needles taken from the ground after they had been shed from treated trees showed concentrations of ten to thirty parts per million As_2O_3 on dry weight of needles.

The toxic hazard of these concentrations to people handling trees after felling appears small. The arsenic content for a whole log averages about two to five parts per million. It is unlikely that this concentration is sufficient to affect the pulping properties of the timber, and practical test has shown that it has no effect on sawing and conversion; arsenic-treated logs sawing exactly as unpoisoned logs of similar moisture content.

It has been suggested that there may be a spread of arsenic toxicity from treated trees to adjoining untreated trees through root grafts and root contacts. No such effect has yet been observed and it seems unlikely that it will occur in this way, owing to the observed small movement of poison downwards from the point of application. Poison reaching the forest floor contained in needles of treated trees would seem a more likely means by which the roots of adjacent trees would be affected, although this has not been observed to cause injury in these experiments.

Discussion

Economics of the Technique

The results reported are promising, particularly with sodium arsenite applied to band-girdled trees. However, the trials were not sufficiently extensive to permit an accurate assessment of the economics of the application. Large-scale trials are now under way to examine this for pine, spruce and larch thinnings. In addition to greater convenience, and ease of peeling, it seems likely that the considerable reduction of weight per unit volume of wood of poisoned trees will result in a saving in handling and extraction costs.

Methods of Application

Before starting the large-scale trials mentioned above, various methods of preparing band girdles for treatments were examined. Preparation of the girdle can be very time-consuming for some species. The best procedure tried has been to use a sharp, curved billhook, to make a cut through the bark around the stem at the top and bottom edges of the girdle; the 'sleeve' of bark between these two cuts can then be readily peeled off by means of a hand-peeling tool. In recent work using this procedure, a team of five girdlers and one painter was able to girdle and poison over 100 trees (average girth thirty inches) per hour at a cost of approximately twopence per tree.

It was found essential *to apply the solution to thoroughly wet* the whole surface of the exposed sapwood completely around the tree. Any patches remaining untreated usually result in living strips of cambium and a tight bark.

Application to Other Species

In 1954 the technique was tested on a number of hardwood species, including oak, beech, ash, birch, chestnut, elm and sycamore. First results are quite promising as peeling has been eased, but there has not been a pronounced loss of weight per unit volume of wood as was the case for pine, spruce and larch.

Trials of Non-arsenical Compounds

Recent tests of sodium chlorate, ammonium sulphamate, and the sodium salts of 2, 4-D and 2, 4, 5-T at Alice Holt Forest, have shown these compounds to be less effective than sodium arsenite when applied to band girdles. Trials by Cook and Hamilton (5), Wilcox (12), and Berntsen (2), included zinc chloride, ammonium sulphamate, copper sulphate, 2, 4, 5-T, creosote, PCP, soluble borates, borate/chlorate mixtures, sodium monochloracetate, chloracetaldehyde, and several amine salts of arsenic. None of these compounds proved as cheap or effective as sodium arsenite solution. In 1954 extensive tests in Germany by Glaeser (8), of nearly 100 compounds, revealed none equal to arsenite, although some promise was obtained with thirty per cent ammonium bifluoride.

Summary

The trials discussed are a series of preliminary tests of methods of facilitating bark removal by killing trees chemically before felling and peeling.

Results may be summarised as follows:

(1) Various tree poisoning techniques were compared for Corsican pine, Japanese larch and Douglas fir, using *sodium arsenite or ammonium sulphamate as toxic chemicals.*

(2) Sodium arsenite in forty per cent (As_2O_3) equivalent solution, applied to band girdles in late spring, was found to facilitate bark peeling in autumn and spring following treatment except in Douglas fir. Treatment also considerably reduced the weight of wood per unit volume.

(3) Ammonium sulphamate, sodium chlorate, sodium 2, 4-D and 2, 4, 5-T have proved much less effective in assisting bark removal.

(4) A number of methods of poison application were tested, including band girdles and frill girdles, bore holes, cups or grooves cut into the stems. Band girdles three to six inches wide proved most effective, although a groove girdle followed by application of poison as a paste was promising. but more troublesome to apply, than band girdles painted with solution.

(5) Douglas fir was most difficult to kill, and only showed loosening of bark after application of impractical quantities of sodium arsenite.

(6) No serious attack by fungi or insects was observed on treated trees.

(7) The toxic hazards of using sodium arsenite and the effect of residual arsenic on utilisation and on the surrounding crop are discussed.

(8) The technique holds considerable promise and is now under test in a large-scale costing trial on conifers. It is also being examined for application to hardwood species. (See Photos 18 and 19.)

REFERENCES

ANON. (1951). *The Chemical Killing of Trees to Facilitate Bark Removal.* N.E. Pulpwood Research Centre, Goreham, New Hampshire. Jan. 1951.

BERNTSEN, CARL M. (1954). *Some Results of Chemical Debarking on Sitka Spruce. Western Hemlock and Red Alder.* Pacific N.W. For. and Range Expt. Station. Res. Note No. 104.

COOK, DAVID B. (1944). Sodium Arsenite as a Tree Killer. *Jour. For.* 42: 141-3.

—— (1953). Chemi-peeling and Wild life. *New York State Conservationist,* June-July 1953.

——, and HAMILTON, LAWRENCE S. (1953). Chemi-peeling Pulpwood in New York. *Jour. For.* 51 : 566-9.

DE MOISY, RALPH G. (1950). *Tree Poisoning Facilitates Bark Removal.* U.S. Inst. For. Products Circular No. 9.

—— (1952). *Progress Report on Chemical Debarking in Washington.* U.S. Inst. For. Prods. New Wood-Use Series No. 19.

GLAESER, H. (1954). Die chemische Entrindung, ein Beitrag zur Lösung des Entrindungsproblems. *Allg. Forst. und Jagdzeitung,* 125 (9): 306-11.

HOLMES, G. D. (1952). Chemical Killing of Trees to Facilitate Bark Removal. *For. Comm. Rep. For. Res.* p. 42.

MCINTOSH, D. C. (1949). *Effect of Chemical Treatment of Trees on Changes in Weight of Wood.* For. Prods. Res. Labs., Ottawa. *Mimeo,* 0-144.

—— (1951). *The Effects of Chemical Treatment of Pulpwood Trees.* Canad. Dept. of Resources and Dev. Bull. No. 100.

WILCOX, HUGH (1954). Some Results from the Chemical Treatment of Trees to Facilitate Bark Removal. *Jour. For.* 52 (7) p. 522.

BARR AND STROUD DENDROMETER, TYPE F.P.7

By J. N. R. JEFFERS

(52— —087.1)

THE measurement of the volumes of standing trees is necessary for both forest management and forest research. While, for forest management, it is sufficient to measure parts of the tree which are readily accessible, or which can be readily estimated from the ground, e.g., breast height girth and total height, and to convert these measurements into volumes by means of standard volume or tariff tables, more direct measurements of volumes, involving the measuring of diameters at heights which cannot be reached from the ground, are necessary for forest research. These direct measurements are necessary to obtain reliable estimates of increment in permanent sample plots, and to provide the data upon which volume tables, tariff tables, and yield tables are based. In young stands, it is possible to measure the diameters at heights some distance from the ground with specially constructed ladders or by 'free' climbing in the branches. As the trees become older and taller, climbing becomes slow and dangerous work, and in some cases it is impossible, even with ladders, to measure diameters at heights of more than sixty feet above the ground. The Forestry Commission has some 600 permanent sample plots, in which volume must be measured every six years. In more and more of these plots, measurement by climbing is becoming too slow and too difficult to be considered a reasonable procedure, and it is evident that an alternative method of getting these measurements must be found.

In 1947, Mr. M. V. Laurie, the Chief Research Officer, and Dr. F. C. Hummel, the Mensuration Officer, recognised the possibility of using an optical rangefinder for measuring the diameters of trees. The idea was discussed with Mr. Brian Smith and Mr. W. Thomson of the Directorate of Weapons Research of the Ministry of Supply, and they carried out the early development of the dendrometer; without their help, the idea might never have become a reality. The later development of the instrument was done by Messrs. Barr and Stroud of Anniesland, Glasgow, who, in 1953, produced the prototype dendrometer which is described in this report.

Description of Instrument

The prototype dendrometer is a modified rangefinder with a base-length of eight inches, and for which the magnification is ×5.5. An inclinometer is fitted to the rangefinder, so that the levelling bubble appears within the field of view when the instrument is being used, and the inclinometer gives readings of elevations from 0 to 45°, reading directly in the sine of the angle. The instrument can be used for ranges of twelve to seventy yards to the point of measurement, and gives readings of tree diameters from one-and-a-half to thirty inches. Photographs 13 and 14 give external views of the instrument. The weight of the dendrometer alone is three-and-a-half pounds, and, in its stowage and carrying box, the weight is eight-and-three-quarter pounds. The range readings of the dendrometer are converted into diameters by reference to a set of tables provided with the instrument.

Theory of Instrument

The field of view of the instrument is divided into an upper and a lower portion by a fine horizontal line, one part of the tree image being above the line, and the other part below the line, as in Figs. 3 and 4. Both images are erect, and movement of the range working head displaces the lower image along the horizontal line in the field of view relatively to the upper image.

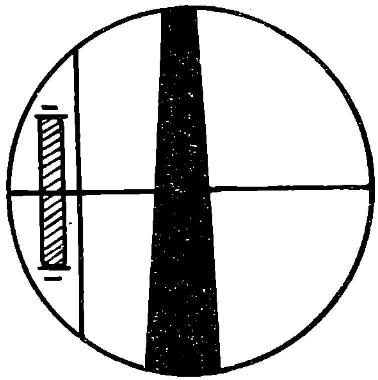


Fig. 3

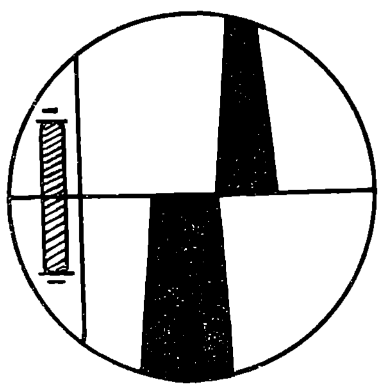
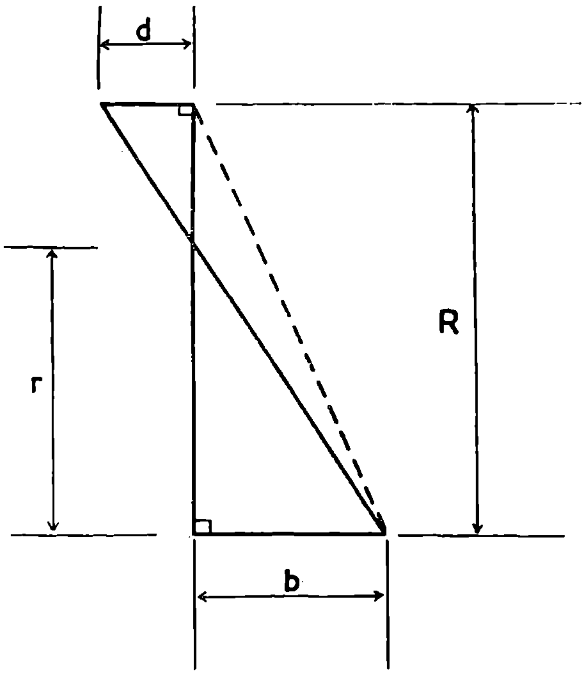


Fig. 4

Appearance of field of view of Dendrometer Type F.P.7

When the images coincide, as in Fig. 3, the reading on the range scale gives the distance to the point of measurement. The lower range is then displaced until the right-hand edge of this image coincides with the left-hand edge of the upper image, as in Fig. 4. The reading on the range scale, in conjunction with the first range reading, gives the diameter of the tree by reference to the tables provided.



By similar triangles

$$d = \frac{b\,(R - r)}{r}$$

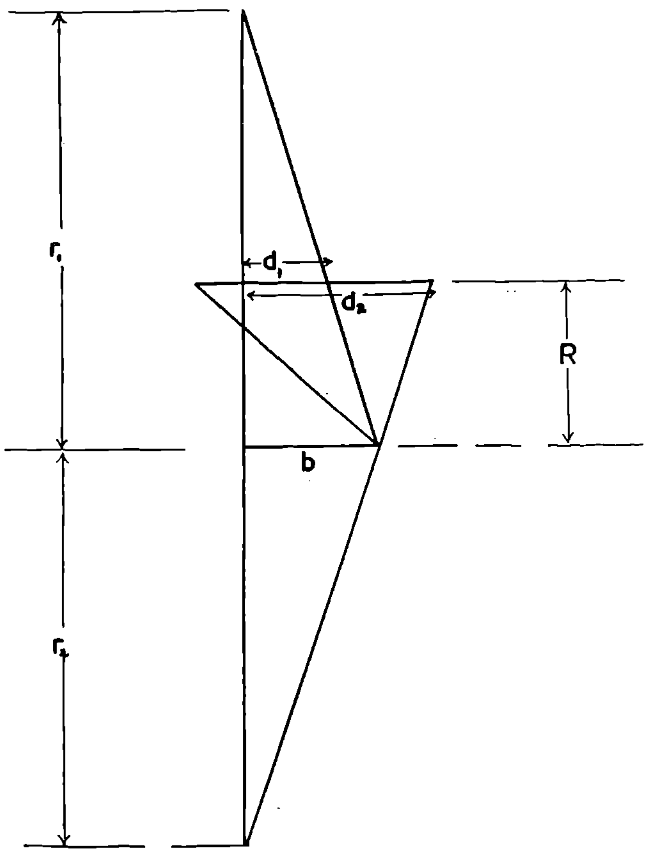
where d is diameter of the tree.
b is the base of the range-finder.
R is the reading of the instrument at full coincidence.
r is the reading of the instrument at edge coincidence.

Fig. 5 Use of coincidence rangefinder as dendrometer: front coincidence solution.

The underlying theory of the instrument is illustrated by Figure 5, which gives the geometrical derivation of the basic formula:

$$d = b\,\frac{(R - r)}{r}$$

where *b* is the base of the rangefinder,
R is the range to the point of measurement,
r is the second range reading,
and *d* is the diameter of the tree.



$$d_1 = \frac{b\,(r_1 - R)}{r_1}$$

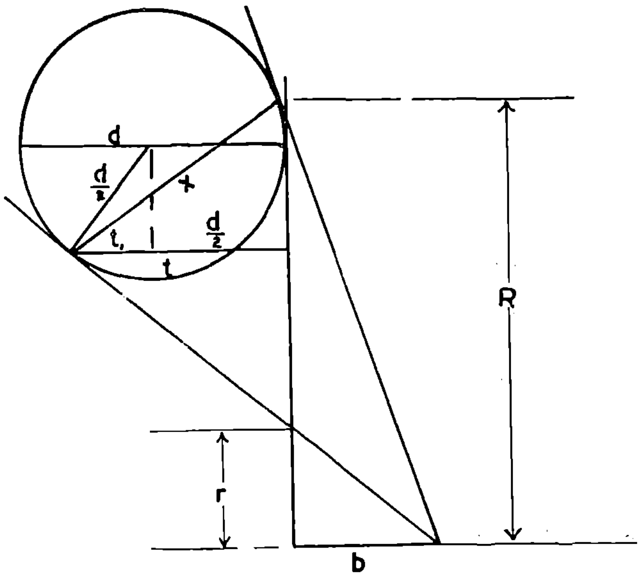
$$d_2 = \frac{b\,(r_2 + R)}{r_2}$$

i.e. $d = b\left(1 - \frac{R}{r}\right)$ with r becoming negative when $d > b$

Fig. 6 Use of coincidence rangefinder as dendrometer: back coincidence solution.

This is the solution by front coincidence and it was this solution which was used in the early development of the dendrometer. At a later stage, however, the back coincidence solution, shown in Fig. 6, was substituted, as it requires the measurement of less acute angles and hence reduces the errors of measurement.

As the cross-section of a tree is roughly circular, it is evident that the instrument does not measure the true diameter, but measures the chord of a section of the circle of cross-section. The difference between the actual diameter of the



d - diameter of tree.
b - length of base of rangefinder.
R - first range reading of dendrometer.
r - second range reading of dendrometer.
x - distance recorded by dendrometer as diameter of tree

There appears to be no simple way of expressing x in terms of the known quantities r, b and d, but it is easy to express t in these terms and to show that d−t is negligible. As x is greater than t, d−x must be even smaller.

$$\frac{t_1}{\frac{1}{2}d} = \frac{r}{\sqrt{r^2+b^2}} \qquad t_1 = \frac{dr}{2\sqrt{r^2+b^2}}$$

$$\therefore \quad t = \frac{dr}{2\sqrt{r^2+b^2}} + \frac{d}{2}$$

Fig. 7 Difference between true diameter and chord of section measured by dendrometer.

tree and the measurement taken by the rangefinder is not of practical importance for the range of values that is encountered. That this is so can be inferred from Fig. 7 and the formulae shown below the figure. Although the proof has been given for the front coincidence solution, the alternative solution is unlikely to give greater errors. No systematic underestimates of diameters have been found in practical tests of the dendrometer.

Comments on the General Design of Instrument

The instrument, in its present form, has been found to be suitable for use in the forest. It was originally intended that the dendrometer should be light enough to be used in the same way as a pair of binoculars, but, although weight has been reduced as much as possible, the prototype needs some support in use. A light forked stick, with only a fraction of the weight of a tripod, has been found sufficient to support the weight of the instrument while readings are being taken. In its stowage box, the dendrometer is portable and is sufficiently protected against damage during transport. Although many optical tree measuring instruments are difficult to use in the heavy shade occurring under some trees, no difficulty in sighting or taking readings has been found with the dendrometer.

The minor faults in the prototype dendrometer are that the position of the range adjusting screw makes it difficult to operate, that the range and elevation scales are not in a position in which they can be easily read, and that the present tables for conversion of instrument readings in diameters and ranges require too much interpolation. The only major fault in the design of the prototype is that the inclinometer cannot record an angle of depression. This reduces the usefulness of the instrument in the forest. These faults have been overcome in the design proposed by Messrs. Barr and Stroud for new models of the dendrometer.

Tests of Accuracy

The makers of the instrument give the 'approximate uncertainty of observation of range measurements, attainable by a reasonably good observer, under average practical conditions' as follows:

APPROXIMATE UNCERTAINTY OF OBSERVATION OF RANGE MEASUREMENTS

Table 35

Range	Allowance in scale reading	Allowance in range
yards	division	inches
15	0.1	0.7
20	0.1	2.5
25	0.1	4.0
30	0.1	6.5
35	0.1	9.0
40	0.1	11.5
70	0.05	20.0
Infinity	0.1	—

For measurements of diameters, the approximate uncertainty of observation is given as 0.1 inch from 1.5 inches to ten inches, and as one per cent from ten to thirty inches. These allowances were calculated under laboratory conditions, however, by sighting the instrument on a well-defined solid. The rough bark of many forest trees does not give a clearly defined edge, and light conditions under trees are frequently poor. Before the dendrometer could be used in the forest, it was necessary, therefore, to test its accuracy under forest conditions. These tests were required to investigate both the bias and the precision of the instrument, and also to test the effects of different observers.

The first trials were designed to test the bias and precision of measurements of range, diameter and height. Standing trees were marked with white tape at points of measured diameter and height, and the ranges, diameters, and heights were measured by the dendrometer from fixed points of known distance from the trees. Several observers took part in these tests, and care was taken to see that they were not influenced by previous measurements, either their own or other observer's! In most of these tests, the dendrometer was supported on a forked stick, but tests were also carried out with the dendrometer on a tripod. In all, 408 sets of readings were taken, over all measurable ranges, diameters, and elevations.

As might be expected, the accuracy of the instrument was partly dependent on the observer. Used by an experienced and careful observer, the measurements of range, diameter, and height were unbiased, but some observers tended to over-estimate diameters. The reason for this over-estimate is suspected to be that observers tend to separate slightly the edges of the images at the second range reading, instead of making them coincide. There was no bias in the measurement of ranges and heights, even when the dendrometer was used by inexperienced observers.

The difference in precision of the readings of individual observers was small, but the readings of inexperienced observers were usually more variable than those of experienced. The precision of the dendrometer, when supported on a forked stick, is expressed in Table 36 by the appropriate standard deviations of individual measurements.

APPROXIMATE STANDARD DEVIATIONS OF INDIVIDUAL MEASUREMENTS

Table 36

	Precision of measurements of :		
	Range (feet)	Height (feet)	Diameter (inches)
Approximate standard deviation ...	± 1.0	± 0.5	± 0.3

Thus, approximately ninety-five per cent of all individual measurements were within ± 2 feet for range, ± 1 foot for height, and ± 0.6 inch for diameter. Supporting the instrument on a fixed tripod slightly improved the precision of the diameter measurements, but had little effect on the precision of the range or height measurements. The slight gain in precision was offset by the greater weight of the combined dendrometer and tripod, which made the instrument less convenient to use in the forest.

No increases in the bias or precision of diameter measurements were observed with increasing distances from the tree, or increasing elevations of the points of measurement. This suggests that the dendrometer can be used from any position within the ranges for which it was designed, i.e., twelve to seventy yards. It is, however, most important that, at the point of measurement, the stem should be clearly visible to the observer. Where the point of measurement was even slightly obscured by a branch, the standard deviations of the readings were increased to at least three times those given in Table 36.

Measurement of Volumes of Standing Trees

Having shown that the dendrometer was reasonably accurate, in forest conditions, for measuring single ranges, diameters, and heights, it was next necessary to find a method of getting the volumes of standing trees, and to test the accuracy of such volumes. Several different methods were suggested, but after trying them in the forest, the following method has been adopted.

(1) The instrument is sighted to the tip of the tree, and the first range reading and the sine reading taken. These two readings give the total height of the tree above the level of the observer's eye.

(2) The position of the point at which the stem has a diameter of three inches (the limit to which volume measurements are usually taken) is estimated from the ground, and the instrument sighted to this point. First and second range readings and the sine readings are taken. By reference to tables, these readings give the timber height of the tree, and also the diameter at this point. Small divergences from a diameter of three inches may be ignored as they have only a very small effect on the total volume of the tree. If the divergence is large, however, a correction may be made when the volume of the tree is calculated.

(3) The sine scale of the inclinometer is set at the nearest unit of 0.1 below the sine reading for timber height, e.g., if the sine reading at the timber height was 0.656, the scale is set at 0.600. The instrument is sighted at the tree, keeping the bubble of the inclinometer between its fiducial marks, and the first and second range readings taken at this point, to obtain, as before, the tree's height and diameter at this point. (If the point of measurement falls on a whorl, or cannot be seen clearly through the foliage, the measurements are taken just below the whorl, and the sine reading corrected.) By reference to tables, the cross-sectional area is obtained from the diameter.

(4) Successive readings from the tree are taken at intervals of 0.1 on the sine scale, e.g., at 0.5, 0.4, 0.3, 0.2, 0.1 and 0, the first and second range readings are taken, and the relevant heights, diameters, and cross-sectional areas are secured.

(5) The position of the lowest point of measurement, usually at the zero readings of the sine scale, is marked with measuring rods with the help of a second operator. The length of this butt section, i.e., from the lowest point of measurement to ground level, is measured with the rods, and the diameter or girth measured half-way up this log.

Fig. 8 shows the points at which measurements are taken on a typical tree.

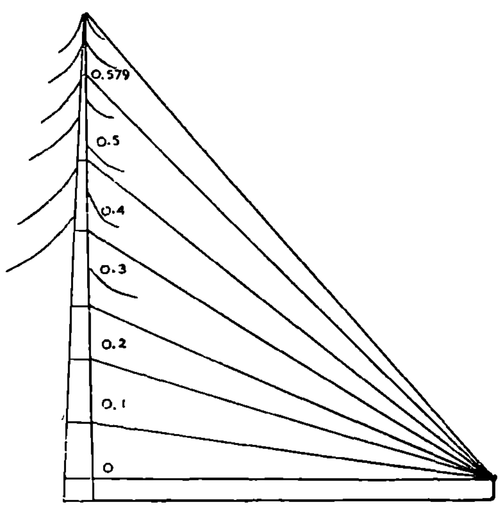


Fig 8. Measurement of volume of a standing tree.

The volumes of the individual sections, except for that of the butt section, are calculated from the appropriate lengths and cross-sectional areas by using Huber's formula.

$$\text{Volume} = h \times \frac{(g_1 + g_2)}{2}$$

where h is the length of the section,
g_1 is the sectional area at the top of the section,
and g_2 is the sectional area at the bottom of the section.

The volume of the butt section is calculated by multiplying the mid-sectional area by the length of the log. The form which is used for recording the readings and calculating the volume is shown, together with a worked example, in Table 37. Although, in normal sample plot procedure, standing sample trees are measured in ten-foot sections, it is not convenient to measure diameters of *sections of equal length* when working with the dendrometer. The method described above works in *sections subtending equal sines* at the instrument, the sections becoming shorter as their diameters, and hence volumes, increase. Greatest weight is therefore given to measurements of the part of the tree which has the biggest volume.

RECORDS AND CALCULATIONS FOR VOLUME OF A STANDING TREE

Table 37 Volumes in hoppus feet

Tree No. and Girth in ins.	Readings			From tables			Calculations					
	1st Range	2nd Range	Sine	Distance (feet)	Diam. (ins.)	Height (feet)	Sect. Area (sq. ft.)	Sums of two previous Sect. Areas	½ Sums	Diff. in Height (feet)	Volume	Total volume of tree
	49.6	—	.668	92.9	—	65	—	—	—	—	—	—
	49.3	55.3	.584	91.3	3.0	56¼	.039	—	—	—	—	—
226	48.0	57.1	.5	84.8	4.2	45¼	.076	.115	.058	11	0.64	—
	47.4	59.1	.4	82.2	5.3	36	.120	.196	.098	9¼	0.93	—
	46.0	60.0	.3	76.7	5.9	26	.149	.269	.135	10	1.35	—
	45.8	60.5	.2	76.0	6.1	18	.159	.308	.154	8	1.23	—
22¼	45.6	61.7	.1	75.3	6.7	10¼	.192	.351	.176	7¼	1.32	—
	45.5	63.5	0	—	7.5	3	.241	.433	.217	7¼	1.63	—
					24					3	0.75	7.85

This method of volume measurement has been used extensively in the forest, and has been found easy to carry out and reasonably quick. It is certainly quicker than measurement by climbing, for trees with heights greater than sixty feet. The absence of any angle of depression on the inclinometer scale limits the positions from which the dendrometer can be used on steep slopes, as, unless trees are measured from positions along the contour, it is frequently impossible to reach the lowest point of measurement with a rod, or to girth the butt-section from the ground. As has been mentioned, this fault has been corrected in the new model.

Tests have been designed to find the accuracy of this method of volume measurement. So far, it has not been possible to find many sites in which such tests can be carried out, as it is necessary to measure the standing trees with the dendrometer and then measure them shortly afterwards, when they have been felled. In the test which has been completed on twenty-seven trees with volumes from five to twenty-five hoppus feet, the standard deviations of individual differences of the volumes measured by the dendrometer from the felled volumes were between 0.3 and 1.00 hoppus feet. The variability of these volume differences does not appear to be correlated with the size of the tree being measured. With experienced observers, the volume measurements are unbiased, but where the observers are over-estimating the diameters, the dendrometer volumes will naturally be over-estimates of the felled volumes.

Future Developments

Experience with the prototype dendrometer has suggested that some small modifications are necessary, but that, even without these, it is a valuable tool in forest research. The instrument will measure the volumes of standing trees with reasonable accuracy, and not only saves considerable time in these measurements, but eliminates the risks involved in climbing tall trees.

The instrument is being used regularly by the Mensuration Section of the Forestry Commission Research Branch for the measurement of standing sample trees in permanent sample plots, and it is likely to become the main tree measuring instrument within the Research Branch.

The present price of the dendrometer is in the region of £350-£400.

APPENDIX I

LIST OF THE MAIN EXPERIMENTAL PROJECTS AND THE LOCALITIES WHERE WORK ON THEM IS CONCENTRATED

While most of the investigations and experiments of the Research Branch are scattered throughout forests all over the country, there are certain areas where work on some projects is more or less concentrated. These are briefly given below :—

NURSERY EXPERIMENTS. Including partial sterilisation of the soil, maintenance of fertility, compost and fertiliser experiments, green cropping, chemical weed control, etc.

Inchnacardoch Forest Nursery, near Fort Augustus.
Newton Nursery, near Elgin.
Benmore Forest Nursery, near Dunoon.
Tulliallan Nursery, near Alloa.
Devilla Forest Nursery, near Alloa.
Bush Nursery, near Edinburgh.
Fleet Forest Nursery, Gatehouse of Fleet.
Kennington Nursery, near Oxford.
Sugar Hill Nursery, near Wareham.

PLANTING EXPERIMENTS ON PEAT.

Kielder Forest (Northumberland).
Clocaenog Forest (Denbighshire).
Beddgelert Forest (Caernarvonshire).
Inchnacardoch Forest (Inverness-shire).
Achnashellach Forest (Ross-shire).

PLANTING EXPERIMENTS ON HEATHLAND.

Croft Pascoe Forest (Cornwall).
Wareham Forest (Dorset).
Wykeham and Broxa in Allerston and Langdale Forests (Yorks.).
Harwood Dale in Langdale Forest (Yorkshire).
Teindland Forest (Morayshire).
Clashindarroch Forest (Aberdeenshire).
Crarae, near Minard, Argyll.

PLANTING EXPERIMENTS ON SAND DUNES.

Newborough Forest (Anglesey).

PLANTING EXPERIMENTS ON CHALK DOWNLAND.

Queen Elizabeth Forest (Buriton) (Hants. and Sussex).
Friston Forest (Sussex).

ESTABLISHMENT OF OAK.

Forest of Dean (Gloucester, Hereford and Monmouth).
Dymock (Gloucester and Hereford).

POPLAR TRIALS.

Harling, Thetford Forest (Norfolk).
Hockham, Thetford Forest (Norfolk).
Yardley Chase (Beds. and Northants).
Quantock Forest (Somerset).
Forest of Dean (Gloucester).

SPECIES PLOTS OR " FOREST GARDENS."

Bedgebury Forest (Kent).
Thetford Chase (Norfolk).
Beddgelert Forest (Caernarvonshire).
Benmore Forest (Argyll).

GENETICS WORK. Grafting, propagating, etc.

Alice Holt Forest (Hants.).
Grizedale Forest (Lancashire).
Bush Nursery (near Edinburgh).

EXPERIMENTAL SEED ORCHARDS.

Rendlesham Forest (Suffolk).

APPENDIX II

STAFF OF THE RESEARCH BRANCH, FORESTRY COMMISSION, AS AT 31st MARCH, 1955

DIRECTORATE OF RESEARCH AND EDUCATION : 25 Savile Row, London, W.1. Tel.: REGent 0221.

J. Macdonald, C.B.E.	Director
Miss A. Brooks, M.B.E.	Senior Executive Officer

MACHINERY.

R. G. Shaw, B.A., A.M.I.Mech.E.	Machinery Research Officer.

UTILISATION DEVELOPMENT.

E. G. Richards, B.Sc.(For.)	Divisional Officer
C. D. Begley, B.Sc.	District Officer
J. R. Aaron, M.A.	,, ,,

FOREST RESEARCH STATION : Alice Holt Lodge, Wrecclesham, Farnham, Surrey. Tel. : Bentley 2255.

M. V. Laurie, O.B.E., M.A., Dip. For.	Conservator, Chief Research Officer
E. C. Harper	Higher Executive Officer

SILVICULTURE (SOUTH) (Alice Holt).

R. F. Wood, B.A., B.Sc.	Divisional Officer
M. Nimmo	District Officer
G. D. Holmes, B.Sc.	,, ,,
J. R. Aldhous, B.A.	,, ,,
A. D. S. Miller, B.Sc.	,, ,,
J. Jobling, B.Sc.	,, ,,
J. M. B. Brown, B.Sc., Dip. For.	,, ,,
W. H. Hinson, B.Sc., Ph.D.	Scientific Officer
G. Buszewicz, Mgr. Ing.	Experimental Officer

SILVICULTURE (NORTH). Government Buildings, Bankhead Avenue, Sighthill, Edinburgh 11.

M. V. Edwards, M.A.	Divisional Officer
J. W. L. Zehetmayr, B.A.	District Officer
R. Faulkner, B.Sc.	,, ,,
R. Lines, B.Sc.	,, ,,

MENSURATION AND CENSUS.

F. C. Hummel, M.A., D.Phil.	Divisional Officer
A. M. Mackenzie	District Officer
G. M. L. Locke, B.Sc.	,, ,,
J. N. R. Jeffers	Forester

FOREST PATHOLOGY.

T. R. Peace, M.A.	Divisional Officer
J. S. Murray, B.Sc.	District Officer
S. Batko, D.Ing.	

FOREST ENTOMOLOGY.

M. Crooke, B.Sc., Ph.D.	District Officer
D. Bevan, B.Sc.	,, ,,
Miss J. Davies, B.Sc.	Experimental Officer

FOREST GENETICS.

J. D. Matthews, B.Sc.	District Officer
A. F. Mitchell, B.A., B.Ag. (For.)	,, ,,

DOCUMENTATION AND PHOTOGRAPHY.

G. D. Kitchingman, M.A., Dip. For.	District Officer
I. A. Anderson	Senior Photographer
Miss T. K. Wood	Photographer

LIST OF PUBLICATIONS

The following papers by members of the Research Branch staff were published during the year ended 31st March, 1955.

Aaron, J. R.	The Use of Forest Produce in Sea and River Defence in England and Wales. *Forest Record* No. 29. H.M.S.O. (1954).
Bevan, D.	The position of the Pine Looper Moth (Bupalus piniarius L.) in Britain in 1953. *Rep. For. Research* (1954). H.M.S.O., pp. 158-63.
Christie, J. M.	Douglas Fir Sample Plots at Tortworth, Gloucestershire. *Rep. For. Research* (1954). H.M.S.O., pp. 127-35.
Crooke, Dr. M.	Forest Insects in the Gale-damaged Woods of North-East Scotland. *Rep. For. Research* (1954). H.M.S.O., pp. 163-9.
Edwards, M. V.	A Summary of Information on *Pinus contorta* with Special Reference to its use in Europe. *Forestry Abstracts.* Vol. 15. No. 4 (1954), pp. 389-96, and Vol. 16, No. 1 (1955), pp. 3-13.
„ „	Norway Spruce Provenance Experiments. *Rep. For. Research* (1954). H.M.S.O., pp. 114-26.
Edwards, M. V., Matthews, J. D., and Buszewicz, G.	East Scotland Scots Pine Seedling Provenance Trial. *Rep. For. Research* (1954). H.M.S.O., pp. 78-83.
Faulkner, R.	Experiments on applying various Forms of Nitrogen to Sitka Spruce Seedbeds in Scotland. *Rep. For. Research* (1954). H.M.S.O., pp. 91-101.
Holmes, G. D.	*Abstract of International Rules for Testing Seed of Forest Tree Species.* Circulated by F.A.O. Rome, March, 1955, as part of Forestry Development Paper No. 4: *Handling Forest Tree Seed.*
„ „	Notes on Study Tour to Sicily. *Proceedings of the 11th Congress of I.U.F.R.O.* (1953), pp. 174-84. Florence, 1954.
„ „	Experiments with Chemical Repellents for Protecting Trees against Rabbits. *Rep. For. Research* (1954). H.M.S.O., pp. 148-58.
Holmes, G. D. and Buszewicz, G.	Experiments with Cold-Wet Pretreatment as a method of Increasing the Germination Rate of Seed of Douglas Fir, Sitka Spruce, and Pinus contorta. *Rep. For. Research* (1954). H.M.S.O., pp. 84-91.
Hummel, F. C.	*The Volume Basal Area Line.* Bulletin No. 24. H.M.S.O. (1955).
	Forestry Practice in Britain: Thinning, Methods and Yields. Part I. *Wood.* June 1954, pp. 241-3, and Part II, July 1954, pp. 292-3.
Hummel, F. C. and Lewis, R. E. A.	The Closewalk Yews, Cowdray Estate, Midhurst, Sussex. *Quarterly Journal of Forestry.* Vol. XLIX, No. 1. Jan. 1955. pp. 35-7.
Jeffers, J. N. R.	Volume Tables for Small Hardwood Trees. *Forest Record* No. 28. H.M.S.O. (1954).
„ „	Relationship between the Percentage of Usable Conifer Seedlings and the Mean Height of Samples. *Rep. For. Research* (1954). H.M.S.O., pp. 101-6.
Kitchingman, G. D.	The Problem of Finding the Information You Want. *Quarterly Journal of Forestry.* Vol. XLVIII. No. 4 (1954), pp. 277-80.

LAURIE, M. V. Forestry Practice in Britain : The Mature Crop. *Wood.* September 1954, pp. 363-5.

LOCKE, G. M. Changes in the Character of the Woodland of a Recently Surveyed County. *Rep. For. Research* (1954). H.M.S.O., pp. 136-44.

MACDONALD, JAMES Tree Planting on Coastal Sands in Great Britain. *The Advancement of Science.* Vol. 11, No. 41 (1954), pp. 33-7.

" " The Afforestation of Peat in Great Britain. *International Peat Symposium*, Dublin (1954).

" " Forestry Research and Experiment in Scotland, 1854-1953. *Scottish Forestry.* Vol. 8, No. 3 (1954), pp. 127-41.

" " The Heathland Nursery. *Irish Forestry.* Vol. 11, No. 2 (1954), pp. 41-7.

MACDONALD, JAMES, FOURT, D. F., and CHRISTIE, J. M. N. Cupressus macrocarpa plantation near Seaford, Sussex. *Quarterly Journal of Forestry.* Vol. XLVIII, No. 2 (1954), pp. 128-31.

MATTHEWS, J. D. Production of Seed by Forest Trees in Britain. *Rep. For. Research* (1954). H.M.S.O., pp. 64-78.

MILLER, A. D. Silvicultural and Economic Aspects of the Rehabilitation of Broadleaved Woodlands. *Quarterly Journal of Forestry.* Vol. XLIX. No. 1 (1955), pp. 38-43.

MITCHELL, A. F. Two old larches at Epsom. *Quarterly Journal of Forestry.* Vol. XLVIII, No. 4 (1954), pp. 293-96.

PEACE, T. R. Experiments on Spraying with D.D.T. to prevent the feeding of Scolytus Beetles on Elm and Consequent Infection with *Ceratostomella ulmi.* *Ann. App. Biol.* Vol. 41, No. 1 (1954), pp. 155-64.

The Testing of Poplars for their Reaction to Disease. *Proceedings of the 11th Congress of I.U.F.R.O.* (1953), pp. 694-705. Florence, 1954.

Observations on Keithia thujina and the possibility of avoiding attack by growing Thuja in Isolated Nurseries. *Rep. For. Research* (1954). H.M.S.O., pp. 144-8.

RICHARDS, E. G. Forestry Practice in Britain : British Timbers. Part I. *Wood.* Nov. 1954, and Part II, Dec. 1954, pp. 456-7 and 486-7.

SHAW, R. G. Forestry Practice in Britain : Extraction of Timber. *Wood.* Aug. 1954, pp. 329-31.

" " Development of Tractors for Operation on Soft Ground. *Rep. For. Research* (1954). H.M.S.O., pp. 170-2.

WOOD, R. F., and NIMMO, M. Trials of Species in Thetford Chase Forest. *Rep. For. Research* (1954). H.M.S.O., pp. 106-14.

ZEHETMAYR, J. W. L. *Experiments in Tree Planting on Peat.* Forestry Commission Bulletin No. 22. H.M.S.O. (1954).

" " Forestry Practice in Britain : Forest Pruning. *Wood.* May 1954, pp. 201-3.

Other Forestry Commission Publications prepared by members of the Research Branch staff were :—

FORESTRY COMMISSION LEAFLET,
No. 32. *Pine Looper Moth.*
H.M.S.O. (1954).

FORESTRY COMMISSION PAMPHLET.
Traps for Grey Squirrels.
Forestry Commission, London (1954).

Printed in Great Britain under the authority of Her Majesty's Stationery Office by McCorquodale & Co., Ltd., London, S.E.1

A.2563. Wt. 3374. K24. 2/56. 557/2.

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH for the year ended March, 1956

LONDON
HER MAJESTY'S STATIONERY OFFICE
1957

ADDRESSES OF PRINCIPAL
RESEARCH OFFICES OF THE FORESTRY COMMISSION

Director of Research and Education:
25 Savile Row, London W.1. (Regent 0221)

Chief Research Officer:
Alice Holt Research Station,
Wrecclesham, Farnham, Surrey (Bentley 2255)

Silviculturist, Scotland and North England:
Forestry Commission,
Government Building, Bankhead Avenue, Sighthill, Edinburgh 11
(Craiglockhart 4010)

CONTENTS

PART III

REPORTS ON RESULTS OF INDIVIDUAL INVESTIGATIONS

APPENDICES

INTRODUCTION

By JAMES MACDONALD

Director of Research and Education

TOWARDS THE END of the year under review, arrangements were completed for the transfer to the Forestry Commission of the famous Arboretum at Westonbirt, near Tetbury, on the borders of Gloucestershire and Wiltshire. The property transferred to the Commission includes the Arboretum extending to 116 acres and, a short distance away, Silk Wood, of 370 acres, in which much experimental planting of exotic trees has been carried out. The Arboretum, which was founded by Mr. R. S. Holford of Westonbirt and expanded by Sir George Holford and the Earls of Morley, his successors, is known all over the world for the extraordinary richness of its contents and for the skill and imagination with which it was planned and developed. The collection of trees and shrubs is of the highest scientific value. To advise them in the management of this property the Commissioners have since appointed a Committee composed of the Honourable L. Palmer (Chairman), The Duke of Beaufort, Professor Sir Harry Champion, Mr. C. M. Floyd, Mr. J. S. L. Gilmour, Sir Edward Salisbury, Sir Eric Savill, Mr. Hiram Winterbotham, and Professor E. W. Yemm. The Arboretum will be managed for the Commission by the Research Branch.

In the introduction to last year's report, reference was made to the increasing importance of subjects such as management and utilisation. To meet the changing circumstances, it has been decided to reorganise the section under Dr. Hummel which dealt with statistics, Census of Woodlands, studies of growth, increment and yield, etc. This section, continuing in Dr. Hummel's charge, will deal with management in the broadest sense and will be divided into three sub-sections, one dealing with statistics, including the Census of Woodlands, one with management of forests and one with economics. The statistical and other work connected with the design of experiments and the analysis and interpretation of the results, hitherto carried out by Mr. J. N. R. Jeffers under Dr. Hummel, will be removed from this section and placed directly under the Chief Research Officer. Arrangements are being made for staffing the new sub-sections.

New members of the staff of the Research Branch are Mr. G. G. Stewart who takes the place of Mr. Zehetmayr in Scotland and Mr. D. W. Henman who was appointed at the close of this year and was posted to Scotland for silvicultural work. On the other hand Mr. J. N. R. Jeffers, who had acted as Statistician, left to take up another appointment. During the year, Mr. R. G. Green of the Forestry and Timber Bureau, Canberra, worked with the Research Branch as a temporary District Officer and carried out some useful pieces of work.

Plans have been prepared for an extension to the Research Station at Alice Holt where accommodation and especially laboratory accommodation is inadequate, and it is hoped that work will commence on the new building before the end of 1956. The extension, which will consist of a three-storied wing to be added to the old building, will provide adequate laboratory space and will also include a seed-store.

The number of visitors to Alice Holt Lodge again increased though not so sharply as during last year when there were 424 visitors. This year, visitors numbered 448 and included forest officers and others from the following countries—Austria, Australia, Burma, British Guiana, Canada, Cyprus, Denmark, Finland, France, Germany, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Sweden, Southern Rhodesia, Turkey, Thailand, Uganda, and the United States of America.

Alice Holt was also visited by the Association of Applied Biologists, the staff of the East Malling Research Station and various other parties including the Fabian Society Summer Schools, the Bognor Regis Natural History Society and members of a course for foreign students, conducted by the British Council. Students from the Imperial Forestry Institute and the Universities of Aberdeen and Edinburgh and from the University College of North Wales, Bangor, paid their usual visit and a party from Eton College also visited the station.

Experimental areas in different parts of the country were seen by visitors from Australia, Canada, Denmark, Ireland and Sweden, by forestry students from Edinburgh, Aberdeen and Bangor, by botany students from Manchester University and by school children in Yorkshire. A party of science students from a school in Oxford carried out investigations in one of our experimental areas in Argyll while most of the Universities sent their forestry students to one or other of the main experimental centres. Members of the Scottish Peat Committee visited the experimental centre on the Lon Mor, Inchnacardoch Forest, where work on the afforestation of peat has been in progress for many years.

The Director attended the meeting of the Permanent Committee of the International Union of Forest Research Organisations which was held in Stockholm in September, 1955. Mr. E. G. Richards, Utilisation Development Officer, visited Switzerland and Germany in September, 1955, to study the use of sawmill and forest wastes in the manufacture of board and he also attended the first session of the Joint F.A.O./E.C.E. Committee on Forest Working Techniques and the Training of Forest Workers held in Paris in December of that year. The F.A.O./E.C.E. Working Party on Forest and Forest Products Statistics held at Geneva in January, 1956, was attended by Dr. F. C. Hummel, while Mr. T. R. Peace was present at the session of the International Poplar Commission in Spain in April, 1955. Mr. R. Lines paid a visit to Ireland to study the older plantations of *Pinus contorta* in that country and Mr. J. W. L. Zehetmayr, in connexion with his writing up of the work on the afforestation of heathlands, visited heathland plantations in Denmark, Holland and Germany in September, 1955. Dr. M. Crooke in June, 1955, went to Germany to study large scale operations against the nun moth with the Todd Insecticidal Fog Applicator, while Mr. D. Bevan and Miss J. Davies, also of the entomology section, visited Arnhem in the Netherlands in February, 1956, to study the research methods used by Dr. Klomp of that town. Mr. A. D. Miller attended the course on Forest Management conducted by the Imperial Forestry Institute in July, 1955, this course included study at Oxford and in forests both in this country and on the Continent.

The Director gave a lecture to the students attending the British Council's Course on Forestry which was conducted for them at Oxford by Professor Champion and his staff, and various members of the research staff gave lectures at training courses at Northerwood House and at the Short Courses for Woodmen at Chatsworth and elsewhere. Members of the staff of the pathology and entomology sections gave instruction in their subjects at the Commission's Forester Training Schools.

INTRODUCTION

The Advisory Committee on Forest Research held one meeting during the year, at Bangor, where the authorities of the University College of North Wales kindly placed a meeting-room at their disposal. Members of the Committee inspected experimental work in the forests of Beddgelert, Gwydyr and Newborough Warren. The Sub-Committee on Nursery Nutrition held its annual meeting at Wareham in October, 1955.

The Advisory Committee on the Utilisation of Home Grown Timber met twice during the year, in London, to review the progress of the work of the Utilisation Section. Mr. E. G. Richards, head of this section, acted as one of the joint Secretaries to the Committee on Marketing. Close liaison has been maintained with the Department of Scientific and Industrial Research and the Forest Products Research Laboratory at Princes Risborough. At Princes Risborough the programme of testing home-grown timbers has been maintained and we are indebted to the Director and his staff for the help they have so willingly given in this work. Valuable assistance has also been given in this field by the Timber Development Association and the British Leather Manufacturers Association and thanks are due likewise to the Directors of those organisations.

Close contacts have also been maintained with the Imperial Forestry Institute, the Rothamsted Experimental Station, the Macaulay Institute for Soil Research, and with the National Institute of Agricultural Engineering and much valuable assistance has been obtained from these Institutes for which we are most grateful.

The organisation of the twelfth Congress of the International Union of Forest Research Organisations, held in Oxford in July, 1956, involved many of the research officers in additional work. Arrangements for the Congress were almost completed by the end of the year under review.

During the year, among the various publications which were issued, there were three major works in the form of Bulletins. One by Dr. Hummel entitled *The Volume—Basal Area Line*, was a study in the field of forest mensuration; another by Mr. R. F. Wood—*Studies of North West American Forests in Relation to Silviculture in Great Britain*—was based on work which he carried out, mainly in British Columbia, during his tenure of a Nuffield Foundation Fellowship; the third, by an Australian forestry graduate, Mr. C. W. Yeatman—*Tree Root Development on Upland Heaths*—was the result of a detailed study of root development in certain of the Commission's experimental areas at Allerston and elsewhere.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE

Chief Research Officer

The Season

THE MOST NOTABLE features of the year 1955 were the bitter weather of February and the fine sunny period from July to September, which will be remembered as one of the finest summers of this century. For the second year in succession there was an unusual lack of rain in April, there being an absolute drought over much of the country from April 10th to 24th. However, by contrast, May was an unusually wet month. The coldness of the first half of the year somewhat delayed leafing and flowering.

June was cool and changeable but from July 6th an almost unbroken spell of warm, dry, sunny weather began which lasted in many places until the first week of September. July and August together were the warmest since 1911, and in England and Wales only three years have been dryer since 1921. The dry weather continued in September and October in the eastern parts of the country and again generally there was a widespread water shortage which lasted well into 1956. Flower bud formation was exceptionally prolific for most tree species throughout the country. Drought effects on newly planted or established tree crops were not as plentiful as expected—only Japanese larch on shallow soils suffering badly. It was the worst year for drought crack in fast-growing pole crops of conifers since 1947.

The weather of October, November and December, 1955, was not severe, but January, 1956, began with widespread south-westerly gales which did considerable damage. February was very cold with periods of continuous frost and a good deal of snow. Nursery work was delayed by the bad weather, and there were many losses by repeated heaving of small plants by the frost. March, as is so common in Britain, was dry and sunny, with a high fire hazard. In fact there were greater losses from fires in March than throughout the whole of the previous dry summer.

PART I

This part of the Report deals with current work carried out by the various sections of the Forestry Commission Research Branch. Only the more important items of work are mentioned in this summary.

Forest Tree Seed Investigations

SEED STORAGE. Conifer seed stored for five years in a dry condition in sealed containers at 36°F. still showed practically no fall in germinative capacity or energy. If the containers were stored at normal air temperatures in an unheated room, deterioration was rapid after the fourth year.

SEED PRETREATMENT. In experiments to try and improve the germination of seed of difficult species by pre-treating the seed, it was found that moderately good germination (40%) of *Pinus peuce* could be obtained by stratification in moist peat at 36°F. for 8-12 weeks. *Tilia platyphyllos* seed, if extracted from the fruit, soaked in concentrated sulphuric acid and then stratified in moist peat for five months, showed a substantial improvement in germinative power.

BIOCHEMICAL TESTING. The vital staining method using 2, 3, 5-triphenyltetrazolium bromide has been approved by the International Seed Testing Association for use with slow germinating species until methods of testing actual germination can be developed. The suggestion that misleading results in using the tetrazolium method may be obtained if attention is not paid to staining of the endosperm as well as the embryo has not been confirmed in practice. The results of many hundreds of tests based entirely on embryo staining have shown consistently high correlation with the results of standard germination tests.

GERMINATION TESTS OF BEECH NUTS. It is found, rather unexpectedly, that beech seeds germinate more rapidly in the laboratory at temperatures of 35° to 40°F. than at the more usual germination test temperatures of 70°-85°F.

SEED MOISTURE DETERMINATION. Tests with a grain moisture hygrometer indicate that it gives accurate estimates of the moisture content of bulk seed at levels of moisture below 20 per cent. It is now being calibrated for use with various different tree species.

Nursery Investigations

PARTIAL STERILISATION. Work has been concentrated on trying to find alternative methods to the standard formalin drench treatment, that are easier to apply and cheaper. Applications of undiluted formalin as a surface spray have proved rather less satisfactory on the whole. Chloropicrin injected into the soil has frequently given better results than the formalin drench, but is more expensive. Shell "C.B.P.-55" has given even more promising initial indications, but unfortunately it has been difficult to obtain this chemical. Autumn sterilisation, by any method, has never proved less effective than spring sterilisation and is sometimes much superior. Nurseries vary greatly in their responsiveness to sterilisation treatments, and, without doing actual experiments in a particular nursery, we still do not know whether partial sterilisation, either with formalin or other chemicals, is likely to be beneficial.

NURSERY MANURING. Apart from experiments done under the control of the Nursery Nutrition Sub-Committee and reported upon in Part II, a number of special nursery manurial experiments have been carried out. Experiments with higher than normal rates of application of nitrogen, phosphorus and potassium indicated, in the Scottish nurseries where it was tried, that while no benefit was obtained from extra nitrogen and potassium, very marked growth responses were obtained from increased amounts of phosphorus. The season was very dry, which may account for failure to respond to more nitrogen. The responses to increased amounts of phosphorus confirm indications obtained in the Nursery Nutrition Sub-Committee's experiments and suggest that higher levels of phosphate manuring would be beneficial.

Experiments with Douglas fir and Japanese larch—both fast growing species that may become too big with the full fertiliser applications normally prescribed for the pines and spruces—showed few clear growth differences for different levels of nitrogenous fertilisers. Where a difference was obtained, early frosts in the autumn did less damage to the larger more heavily manured plants than to the smaller plants receiving less nitrogenous fertiliser. In other cases, no difference in frost susceptibility was found. The lack of response to the different fertiliser rates was probably connected with the unusually dry growing season.

In the long-term fertility experiments in which regimes of mineral fertiliser manuring are compared with manuring with hopwaste or compost, the compost plots after six years again showed a small superiority over the plots receiving artificials only.

In a heavy soil nursery in Wales, working powdered charcoal into the soil caused a reduction of growth in Sitka spruce and Japanese larch seedlings. Weeding was also reduced. The effects of "Krilium" soil conditioner applied to a similar soil in 1952, when it caused an initial improvement in tilth but a reduction in seedling growth, had completely disappeared by 1955.

SEEDBED COVERING. While best results were obtained with a 3/16 inch depth of cover with Sitka spruce and *Tsuga*, in other experiments, *Abies procera* and *Abies lowiana* did best with half inch to three-quarter inch depth of cover—thinner layers of cover producing markedly inferior results. There was, however, some inconsistency between results in different nurseries, and more trials are necessary before confident recommendations on the best depth of cover for *Abies* seedbeds can be made. In tests with different colours of grit for seedbed covering, it was found that temperatures under dark coloured grits were up to 10°F. higher than under white grits.

SEEDBED IRRIGATION. In this dry summer, overhead sprayline irrigation produced seedlings over 50 per cent. taller than those in un-irrigated beds. There was no appreciable difference in survival.

WEED CONTROL. The search continues for substances that have even greater selectivity for weeds without damaging conifer seedlings than the, now widely adopted, Tractor Vaporising Oil (T.V.O.). Tests of "Shellspark" (a new vaporising oil) showed it to be equally good. Numerous other substances were tried both as pre- and post-emergence sprays, but all were more toxic to conifer seedlings than T.V.O., though two new weedkilling materials which have shown promise in the United States of America, namely, "C.D.A.A." and C.D.E.C.", seem to warrant further trials as pre-emergent weedkillers.

SUMMER SHADING OF SEEDBEDS. The hot dry summer of 1955 provided excellent conditions for testing the effect of covering seedbeds with lath shelters. This was done in an experiment whenever the maximum screen temperature exceeded 70°F. for two consecutive days, and showed that there was no difference in survival or growth between the shaded and unshaded beds of the species under test, namely Japanese larch, Douglas fir, Norway spruce, lodgepole pine and *Abies* sp. This suggests that, for these species, the expense of summer shading may not be justified.

HANDLING AND STORAGE OF PLANTS. Wrapping bundles of plants in polythene sheet was the best of a number of protective treatments, and was the only treatment that resulted in 100 per cent. survival on planting after twenty days, Survival was closely related to the moisture content of the plant. In practice, polythene bags are easier to use than polythene sheet.

Afforestation Problems

Mechanical Planting

Trials with the "Lowther" Planting Machine on already ploughed ground under a variety of conditions gave promising results. The machine is being modified to suit our conditions better.

Afforestation of Limiting Sites

At Croft Pascoe, on the exposed Lizard Peninsula of Cornwall, afforestation experiments on the soils derived from serpentine rock have made a promising start. Broom grows vigorously and will be a useful nurse. Of the many tree species tried, Sitka spruce, lodgepole pine (Coastal provenance), *Pinus radiata* and *Pinus pinaster* show good early growth. Experiments on afforesting difficult sites in Coed Taliesin (Mid-Wales) and Wareham and Purbeck Forests (Dorset), and on smoke-polluted areas in the Pennines, have been continued and extended. At Newborough Warren (Anglesey) a trial of fixing shifting sand by spraying with bitumen emulsion after sowing or planting started well, the seeds germinating readily through the bitumen crust. Excessive exposure, however, caused many casualties in the autumn.

Provenance Studies

LODGEPOLE PINE. Southern coastal provenances have proved more vigorous and hardier than northern coastal provenances or inland provenances. Studies of older plantations in Ireland confirmed this experience. Inland types were also more seriously attacked by the pine sawfly than coastal ones.

EUROPEAN LARCH. Provenance trials laid down three years ago in areas where previous crops had suffered severely from die-back, have already shown interesting results in the establishment stage. Polish larch, from Mala Wies, has grown the fastest and has shown the fewest casualties, with Sudeten larch (Moravia) generally second, and better at this stage than a number of Scottish lots. Munsterthal (Alpine) larch was the poorest on all counts.

REHABILITATION OF DERELICT WOODLANDS. A costed experiment in dealing with dense rhododendron showed that to clear five-foot wide strips at ten-foot intervals and plant them, cost one-third of the cost of complete clearing and planting—ten-foot strips at ten-foot intervals being intermediate in expense. Whether the initial economy from partial clearance will be more than offset by later expenditure in tending the planted trees remains to be seen. In hazel coppice some new experiments have been started to compare the economics of partial clearance, underplanting, and complete clearance, using both conifers as catch crops or nurses, and broadleaved trees. In some treatments large transplants, about three feet high, were used, to see whether weeding costs can be reduced thereby.

MECHANICAL SCRUB CLEARANCE. Further trials of various mechanical methods of scrub clearance in which the "Fleco" tree cutter, a "grubber blade" (both mounted on powerful tracked tractors), the "Sabre" circular saw, and a weighted "anchor chain" dragged between two tractors, were compared. The work is still in its early stages and comparative costs cannot yet be given. It is clear however, that the operation of burning or otherwise disposing of the debris is likely to be as or more expensive than the actual clearing operation.

CHEMICAL WEED CONTROL. Work on the control of woody weeds continues. First indications are that rhododendron can be fairly effectively controlled by applying ammonium sulphamate solution to cut stumps. Basal bark spraying of oak and birch coppice with formulations of 2, 4, 5, T and 2, 4-D show some promise, but more experimentation is necessary to find the best treatment. Control of heather with 2, 4-D in oil has been fairly successful, but the best way of doing this has not yet been worked out. If a successful and cheap method of killing heather can be found, it may be very useful as a follow-up treatment after ploughing, to delay the re-invasion of the heather. Some experiments in the chemical control of vegetation in fire traces and along fence lines have been started.

CHEMICAL BARK PEELING. Following the experiments described in last year's report, a large-scale costed trial on conifers has given disappointing results, owing to tightening of the bark at the top of the treated trees. In hardwoods, though peeling is usually facilitated by poisoning with sodium arsenite, it is found that in oak, the tannin content of the bark is seriously reduced.

CHEMICAL REPELLENTS. Patch sowings of conifers, if covered with coarse grit and then sprayed with bitumen, were effectively protected against field mice. The spray without the grit gave very little protection. A number of repellent seed dressings are being tested, and experiments on the protection of planted trees against rodents and deer continue.

Forest Ecology

In clay soils, different intensities of draining had corresponding effects on the winter wetness of the clay, but in the summer, all treatments became equally dry, reaching the wilting point for considerable periods. How far draining permits tree roots to penetrate deeper and tap moister layers of soil in summer can only be assessed when the planted trees are older.

Studies of the growth of Corsican pine and the conditions under which it is growing throughout Britain are not yet complete, but have yielded useful information on the factors limiting its healthy growth in many places. Exposure to wind in particular renders it liable to attacks by the fungus *Brunchorstia destruens*.

Observations on the natural regeneration of beech at Watlington in the Chilterns have not shown any clear correlation between the survival of seedlings and the degree of shade. Nor has trenching to remove root competition noticeably improved survival, though it has resulted in increased growth. At Slindon Park, Sussex, protection from birds by netting resulted in a significant increase in the number of beech seedlings. Additions of ground chalk to the acid surface soil improved seedling growth.

SOILS. In the newly-established soils section work has mainly been concentrated on working out and testing techniques for analysis of the main plant nutrients in soils and in plant material. Over 200 soil samples from manuring experiments were analysed for total phosphate, and a number of other analyses and tests were carried out for various sections of the Research Branch.

Poplars

Ninety-nine varietal trial plots, representing sixty-one different clones, were planted during the winter. At nine of the major trial areas a plot of a highly canker-susceptible clone was also planted. There are now 316 clones in the collection, of which 176 have been planted in the populetum since 1953.

Eight new silvicultural experiments have been planted, half of which are of long-term duration. A total of thirty-five experiments are being maintained and periodically assessed.

Over 23,000 cuttings of the standard varieties have again been distributed to outside nurseries, bringing the number despatched from Alice Holt since the distribution scheme started in 1949 to over 178,000.

Investigations on bacterial canker of poplar have continued, and the current year's work on inoculation of clones under trial has been carried out at Fenrow Nursery, Rendlesham Forest, Suffolk.

Forest Genetics

The survey of seed sources in Scotland was completed and has been extended to North-West England. The selection of outstanding phenotypes or "plus trees" has also continued, and 2,002 such trees of all species are now marked and recorded. Collections of grafted clones from these are being built up, over 8,000 grafts (out of 11,600 made the previous spring), representing 386 parent trees, having become successfully established. Grafts made in previous years from "plus" trees have been planted out in tree banks and in replicated clonal trials. Seed orchards have now been formed at eleven sites for the larches, Scots pine, Douglas fir and beech, and include orchards for the production of first generation hybrid larch seed from "plus" parents of both European and Japanese larch. In one of these (Newton, Morayshire), a large-scale programme of controlled cross pollination was carried out, 5,031 female flowers being isolated and pollinated, representing 115 cross and 19 self pollinations. The seed from this operation will be available for sowing in the spring of 1957. Work has continued on methods of improving vegetative propagation by cuttings and layering. Further experiments on the stimulation of fruiting by girdling and by the application of fertilisers were carried out, and trials of different methods of shoot control in larches to get maximum flowering were continued.

Studies of Management, Growth and Yield

Attention has been given to problems more directly connected with forest management. An investigation of methods of making assessments of the growing stock for working plan purposes was carried out in Inverliever Forest, Argyll, using aerial photographs for stand classification, supplemented by basal area estimates by the relascope method and a limited amount of height measuring, together with combination of measured and visually assessed samples. Adequately accurate estimates of the growing stock were obtained at a cost of about 2/6d. per acre. Methods of determining the increment were also worked out.

Studies of the best ways of improving abnormal age-class distribution were made, and general questions of working plan procedure investigated.

In the Census of Woodlands, four counties with an area of 184,000 acres were surveyed.

Sample plot work was continued. Of the 49 new plots established, 21 were in spacing experiments and fifteen in different species in the forest plots at Bedgebury (Kent). In the Bowmont Norway spruce thinning plots, remeasurement showed that the heavily thinned (D-grade) plots still had a higher total volume production per acre than the lighter (C and B grade) thinning plots or the light crown thinning plot. A provisional yield table has been prepared for Western hemlock, *Tsuga heterophylla*, and methods of using tariff tables for the estimation of standing crop volumes have been worked out.

Forest Pathology

The year has not been notable from the pathological point of view though *Sclerophoma pithyophila* appeared for the first time as a serious defoliator of Scots pine, and drought crack occurred on a serious scale for the first time since 1947.

The suspected relationship between the fungus *Rhizina inflata*, old fire sites and "Group Dying" of conifers has received further support, and warnings have been issued to forests affected, suggesting restrictions on the lighting of fires.

Work on *Fomes annosus* has now become the largest project under way, probably its rightful position considering the economic losses for which it is responsible. One aspect of the work on this fungus is the attempt to estimate more accurately than we can at present, the extent of those losses. So far, one large-scale experiment, covering eighteen acres, has been set up to study the effect of various treatments, in a first rotation crop, on *Fomes* attack in the second rotation. A great deal of survey work has been done to select sites for other experiments.

Large-scale inoculations of poplar clones with bacterial canker are still being continued. Results have proved unexpectedly consistent from year to year, and definite results are beginning to emerge, which should prove very helpful in the choice of varieties in the future.

A sampling survey of elm disease (*Ceratostomella ulmi*), the first since 1949, indicated that the disease had made very little progress. Far more trees had been felled for other reasons, such as road widening, than had succumbed to the fungus.

The work continues to be spread over a large number of diseases, to many of which only very incomplete attention can be given. The number of inquiries still tends to increase, but many of them tie in with subjects under investigation, and others add to our still very incomplete knowledge of tree diseases in Great Britain.

Forest Entomology

Work on the pine looper *Bupalus piniarius* L. has been continued. The winter pupal survey revealed that populations generally remained small despite the apparently favourable summer season. In a few localities, such as a private estate in the Moray coast region, Tentsmuir Forest in Fife, and some parts of East Anglia, rather high but not immediately threatening population densities have been recorded. A study plot for intensive field investigations has been established in the Elveden beat of Thetford Chase. In the laboratory, studies on the relationship of female pupal weight to fecundity, on larval development, and on the biology of some of the parasites of the pine looper have been made.

In the gale damaged areas in north-east Scotland the epidemic of the pine shoot beetle, *Myelophilus piniperda* L., has resulted in severe and widespread crown deformation in pine crops of all ages. Despite the drought season, breeding in, and killing of, standing trees has in the main been restricted to the remnants of the woods devastated by the gale. Further investigation of the increase in numbers of the pine weevil, *Hylobius abietis* L. has shown that 1955 was the peak year for the emergence of adult weevils. A natural decline in these populations should now occur and, in general, it is thought that replanting of the blown woodlands with conifers should be possible in 1957 so long as adequate attention is paid to those weevils remaining on the areas.

Further trials with various insecticides for the protection of newly formed conifer plantations against the attacks of the pine weevil have been carried out. The results are encouraging, and it is hoped to make definite practical recommendations for control at the end of a further season's experimentation.

A larch bark beetle, *Ips cembrae* Heer., new to Britain, has been discovered in a number of localities where the presence of blown timber has favoured its increase. It is thought that the species entered the country on the post-war shipments of German timber.

A countrywide survey of larch sawflies has been made. With the exception of some rather serious attacks of *Anoplonyx destructor* Bens. which have resulted in severe or complete defoliation, numbers of most species are generally low.

A number of trials with a fogging machine have been made, but the results to date are very contradictory; work continues in an effort to clarify the position.

A weevil, *Curculio elephas* Gyll., which does not occur in Britain, was imported in infested sweet chestnuts. Prompt measures to disinfest the consignment were taken and these appear to have been entirely successful.

Squirrel Investigations

Analysis of the replies to a questionnaire showed that there is an increase in the percentage of forests with no grey squirrels and a decrease in the percentage with numerous squirrels observed. The amount of damage done was also less than last year. Data were also collected on the occurrence of red squirrels.

Machinery Research

The increasing interest in forestry shown by the makers of agricultural machinery is very noticeable. Instances are seen in the development of light powered winches and improvements in vehicle wheel and tyre equipment.

Nursery operations are very expensive in labour, so they offer great scope for mechanisation. Improvements have been made in machinery for seed sowing and inter-row cultivation.

One-man power saws are increasing in popularity as their weight comes down and their reliability improves. Some progress has been made in machinery for cleaning drains but there is room for improvement in this direction. No conclusive answer can yet be given on machinery for clearing derelict woodland.

Utilisation Development

Following investigations into the suitability and availability of home-grown hardwoods for pulping, referred to in last year's report, proposals for the erection of a hardwood pulp mill at Sudbrook, Monmouthshire have now been advanced. The timber in the house made from small material cut from conifer thinnings has shown very little degrade during the year after erection. Sitka spruce and Norway spruce bark were examined for tannin content, that of Sitka spruce being high (17.5%) and that of Norway spruce low (only 9.4%). Investigations are in progress on the use of timber for wood-wool and in the box, packing case, stillage and pallet manufacturing industries.

Enquiries

In addition to specialised enquiries referred to the appropriate sections, twenty-one general enquiries from members of the public, and four from Commission sources, were dealt with during the year.

PART II

This part of the report consists of accounts of the progress made by workers attached to universities and other institutions. The subjects covered are usually of a more fundamental nature and much of the work is assisted by grants from the Forestry Fund.

Nutrition Problems in Forest Nurseries

Miss Benzian of Rothamsted Experimental Station, who is mainly engaged in writing up the results of experiments done to date, briefly reports on needle-tip burn of Sitka spruce seedlings at Wareham. Trials with various trace elements have shown that this is caused by a copper deficiency, and can be cured by very small applications of copper sulphate. Tip burn is absent in plots treated with hopwaste, which, on analysis, is found to contain sufficient copper, probably through having been steeped in copper vats. Partial sterilisation of nursery beds by applying neat formalin in drills gave results comparable to applying it as a drench.

Soil Profile Development

Dr. Wright of the Macaulay Institute, Aberdeen, has completed and published his investigations on the thinning plots at Culbin Forest, and has shown that abnormal fluctuations in foliar nitrogen, potassium, and magnesium in young Corsican pine can be correlated with soil moisture. Negligible response to phosphorus manuring has again been found on these sand dunes, and a further experiment has been started to test the effect of fertilizer applications of nitrogen, potassium and magnesium.

The study of the effect of tree growth on deep peat at Inchnacardoch Forest has been continued by Mr. W. O. Binns. Vigorous tree growth dries out the surface peat, possibly irreversibly, causing shrinkage and cracking. The phosphate content of the peat is being divided into organic and inorganic fractions.

At Bowmont forest in Selkirkshire, the accumulation of litter under the lighter thinning grades has resulted in physical and chemical changes in the surface soil. Monthly litter collections from each thinning grade are being continued for a full year.

Chemical Constitution of Leaves

Following on observations by Dr. Handley of the Imperial Forestry Institute at Oxford that leaves of certain tree species contain protein-precipitating substances that seem to affect the readiness with which their litter is broken down by fungi, chemical investigations into the nature of these leaf constituents has been undertaken by Dr. H. Raudnitz. Using solvents of increasing polarity, a number of substances have been extracted from rhododendron leaves, and work is progressing on the accumulation of sufficient quantities of them for further investigation.

Soil Mycology

Dr. Ida Levisohn of Bedford College, London University, has continued her researches into soil fungi that form mycorrhizas with tree roots. In the grounds of the college, trials were carried out with mycorrhizal and non-mycorrhizal pine seedlings to compare their behaviour after planting in soil from Wareham

Forest, Dorset. Results of these experiments demonstrated the superior performance of the mycorrhizal trees over the non-mycorrhizal trees. Additional studies confirmed earlier observations which showed that the mere presence of a fungus capable of forming a mycorrhizal association is not in itself a guarantee of satisfactory growth subsequent to planting in the field.

Pot-culture experiments concerned with the effect of *Boletus scaber* on birch and other tree species were continued. Growth stimulation by the rhizosphere activity of *B. scaber* was recorded in two different soils, also in birch litter containing self-sown birch seed.

Studies of the rhizosphere effect of mycorrhizal mycelia on tree cuttings were started by carrying out a survey of mycorrhizal infection in cuttings of endotrophic and ectotrophic species and of such trees which had been observed to possess a certain "mycorrhizal elasticity". As regards the latter category, which includes species of the genera *Populus*, *Salix*, and *Eucalyptus*, cuttings up to several years of age showed, as a rule, no mycorrhizal associations. The suggestion is put forward that the lack of mycorrhizal infection in a number of species of the genera named above is connected with the fast growth of these plants, which growth may induce a deficit in the sugar content of the roots. Such a deficit would, according to Björkman's carbohydrate theory, discourage the formation of mycorrhizas.

Fungal Damage to Roots of Sitka Spruce Seedlings

Mr. D. M. Griffin of the Botany School, University of Cambridge, has concluded his investigations into this subject. After working out a technique for comparative assessment of root damage, he comes to the conclusion, from surveys made in the seasons 1954 and 1955 on samples of Sitka spruce and other coniferous seedlings taken from experiments on partial sterilization of the soil in soil-sick nurseries, that damage by fungal pathogens is insufficient to account, either wholly or chiefly, for the poor growth of seedlings in such nurseries.

Fomes annosus Investigations

Dr. J. Rishbeth of the Botany School, Cambridge University, on his return to this country has again taken up the study of *Fomes annosus*, which causes losses in the pine plantations in East Anglia. The extent of current losses has been assessed, and evidence is quoted of the effectiveness of experimental stump treatment in reducing such loss; a check is being made of the efficiency of large-scale stump creosoting. A survey of some other forests indicates that, as in East Anglia, *F. annosus* is becoming established in first-rotation crops.

The Relationship between Larch Canker, Trichoscyphella and Frost

Dr. J. G. Manners of Southampton University has continued investigations on the lines mentioned in previous reports. The work has included an investigation of the inter-relationships between *T. willkomii* and frost as causes of larch canker, and a study of the taxonomy of *Trichoscyphella*. Cankers, frost cracks and dieback of laterals occurred in trees locally frozen. It is too soon for infection to have appeared in the inoculated trees in this experiment, but more cankers appeared in inoculated than in uninoculated trees. Wetness of the bark intensified frost damage, which was more severe on Alpine than on Polish or Sudeten strains of larch. Several taxonomic problems have been solved, and it has been shown that a *Trichoscyphella*-like fungus associated with cankers on Scots Pine is *Lachnellula schumannii*.

Meria laricis on Larch

Mr. P. Biggs of the Botany Department, Southampton University, is carrying out an investigation of *Meria laricis*, which causes needle-cast of larch. This disease has recently been recorded on hybrid and Japanese larch, whereas it was formerly confined to European larch. Eight cultured strains of the fungus have been recognized, and the validity of these is being investigated. Cross-inoculation experiments, to test the reaction of European, hybrid and Japanese larch to isolates of the various strains from each of these three tree types, are under preparation.

Keithia thujina

This fungus, which causes serious losses in nursery beds of *Thuja plicata*, is being investigated by Mr. R. G. Pawsey of Nottingham University. Studies of conditions affecting infection and spore development have been started, as well as investigations of the life history and the method of over-wintering. The main over-wintering mechanism appears to be in the form of a surface inoculum of ascospores on the plants, which spores remain viable until the following spring.

Soil Faunal Investigations

Dr. P. W. Murphy, on returning from Vienna where he worked on this subject under Professor Kunhelt, continued his investigations at the Rothamsted Experimental Station, Harpenden, Herts. He gives details of investigations of the biology and food habits of oribatid mites present in the soil. The principal species studied were *Steganacarus magnus* (Nic.), *Hermannia gibba* (Koch) and *Tectocepheus velatus* (Mich.), and the aspects investigated included culture methods, food habits, quantitative data of the amount of food ingested, and food preferences of litter-feeding species. The main food sources were leaf litters and fungi. With the former, *S. magnus* showed a preference for broadleaf as opposed to conifer litter, and ash to birch. There was no clear evidence that these three species could exist on a purely fungal diet. Some species had characteristically shaped excrement pellets, and it is likely that it should be possible to identify, at least to a certain extent, the sources of excrement found in the soil. Evidence from these investigations lends support to field observations that the development of some oribatid species is extremely slow, and that under natural conditions the life cycle may occupy at least one year. Adults survived in culture for 74-650 days.

Bioclimatic Studies on the Pine Looper Moth

Dr. N. W. Hussey continued his investigations at Edinburgh on the effect of various combinations of temperature and humidity on adult longevity, mating and oviposition, incubation of eggs, larval development and feeding activity. A number of interesting facts were ascertained, the most important of which was the effect of subjecting early instars to low temperatures; this treatment greatly lengthened the period of the last two instars, even though the latter were kept at favourable temperatures. It is also concluded that the reputed preference of this insect for dry areas is more apparent than real.

Morphological Variation of Conifers

Dr. E. V. Laing and Dr. A. Carlisle of the Forestry Department, Aberdeen University, continued their anatomical studies of European larch, Douglas fir and lodgepole pine. Some silver firs in Scottish policy woods were found to be hybrids between *Abies alba* and *A. nordmanniana*, and also between *A. alba* and *A. cephalonica*. The results of the investigation into the morphology, ecology and history of the native Scots pine forests in Scotland are in course of preparation for publication.

Shelterbelt Research

Dr. J. M. Caborn of the Department of Forestry, Edinburgh University, has completed the first three-year period of the shelterbelt research programme, which was devoted to the investigation of the effects of shelterbelts on micro-climatic factors. Attention is now being concentrated on the structure of shelter-belts and on their establishment, development and subsequent treatment, employing wherever possible the measurement of wind conditions in the vicinity of the belts as a factor in assessing the efficiency of different belt structures. New belts are being studied for information on lay-out, choice of species, establishment and development, and particular attention is being given to the silvicultural problems of rehabilitating derelict and degraded belts, which form such a high proportion of existing shelterbelts. Stocks of trees are being built up for the experimental planting of belts and margins.

PART III

In this section, the results of certain investigations carried out by the Forestry Commission Research Branch are reported in the form of short articles. The main points of interest are summarised below.

Estimation of Seed Content of Cones

G. Buszewicz and G. Holmes describe and illustrate a special knife designed to cut cones accurately in half longitudinally. Preliminary regressions for Scots pine and Corsican pine of the yield of sound seeds per 100 cones corresponding to a given average number of full seeds per cut surface have been worked out, and tentative figures for the yields per bushel of cones are given for various average cone sizes. It was found, incidentally, that, in the north, cones collected in October gave lower germination percentage from sound seeds than cones collected in January—probably because they were not fully ripe at the time of collection. October collections in the south gave equally high germination to January collections.

Seed Testing of the Larches

Five years' work by G. Buszewicz and G. Holmes is summarised, giving results of purity, weight and germination tests of 360 European, Japanese and hybrid larch seed lots. Wide variations in seed purity and weight were found, and the high proportion of empty seeds in all these species was an outstanding feature—50 to 75 per cent on the average; this is probably a reflection of the difficulty in separating empty seeds in the seed cleaning process on account of the small differences in seed density between full and empty seeds. European and hybrid larch were found to germinate more readily than Japanese larch, but the latter could be speeded up by pre-treating the seed at 2°C. in moist conditions before putting it into the germinator.

Seedbed Compaction

R. Faulkner reports on the results of a series of experiments on the compaction of seedbeds by means of a heavy roller just before sowing. The best results were obtained in a range of Scottish nurseries using a roller of twelve inches diameter weighing approximately two hundredweights. Sitka spruce was used as the test species throughout. Heavy rollers over three hundredweights caused, in some cases, a reduction in yields.

Storage of One Year Conifer Seedlings

The results of experiments extending over three years in which different methods of storing seedlings prior to lining out were compared, are reported on by R. Faulkner. "Sheughing" (i.e. heeling in) in the nursery of origin was found to be the best method. Placing the seedlings on a wooden floor and surrounding the roots by damp moss, or storing in boxes in a cool building were also satisfactory. Storage in boxes in uncooled well-ventilated sheds, and storage in boxes with a protection of roofing felt above them, were unsatisfactory. Bundles of 100 plants stored as well as, and sometimes better than, un-bundled plants packed tightly during storage. Sitka spruce was the hardiest species and stored well in "sheughs" from late November to March. Larches may be lifted and stored from December to February, but because of early flushing, they should not be lifted for storing after the end of February but should be left *in situ* and given priority in lining out in late February or early March.

Manuring of Conifer Seedlings in the Forest

In 1950, as a result of improved nursery techniques, a large number of seedlings—both one year and two year, were produced which were considered large enough for direct planting in the forest. An extensive series of trials of manuring, in which strips of seedlings in the forest were manured with substances containing phosphate, potassium, or combinations of nitrogen phosphate and potassium alternating with unmanured strips, was laid down. Reports at the end of the first year's growth indicated generally poor survival—Japanese larch being less satisfactory in this respect than Sitka spruce—while responses to manuring were, in general, small, only one-fifth of the 203 trials showing a visible response. No reports of any damage from soluble phosphate applications were received, and in some cases on the worst sites, manuring proved essential for establishment. At the end of the fourth growing season, a selection of the trials was measured, and soil samples from the subsoil were analysed for total phosphate. There was a fairly strong suggestion that there was a "threshold value" of some 1,150 parts per million of P_2O_5, below which Sitka spruce seedlings showed growth responses to phosphate manuring. The threshold figure for Japanese larch appeared to be somewhat lower.

A Trial of Compost in Planting on Peat

J. W. L. Zehetmayr reports on an experiment, planted in 1938-39, in which additions of hopwaste compost, and of peat from actively growing plantations of the same species as those planted or sown in the experiment, were compared with untreated controls. While no increases in growth were produced by the peat, increases were produced by compost. Phosphate manuring in the controls also produced similar results, and the conclusion arrived at is that there is no need to go beyond the straightforward manuring effect to explain the results. There was, for instance, no indication that mycorrhizal inoculation through the peat had any effect.

European Larch Races

In the third report on the 1931-32 European larch provenance experiments, M. V. Edwards summarises the results of experiments comparing two Scottish provenances (Elchies, Morayshire and Dores, Inverness-shire) and two European origins (Münsterthal, Switzerland, and a strain from Silesia reported to be of Sudeten parentage). The planting was done on a favourable, an intermediate and a marginal site. All four origins gave good survival on the favourable and intermediate sites. On the poor site over 90 per cent of both the Scottish origins survived, as compared with 80 per cent. for the Silesian and about 66 per cent for the Swiss Alpine origin. Height growth was little different on the most favourable and intermediate sites, but on the marginal site that of the Scottish provenances was very much greater than that of the foreign ones, Münsterthal being the poorest. Differences in growth within a provenance, due to the nursery origin of the plants, had almost disappeared on the best sites, but on the marginal sites they persisted even after twenty years. No clear differences in phenology between the provenances could be established, though there was a suggestion that the Münsterthal usually tended to flush earlier. It also suffered worst from canker.

Fecundity of the Pine Looper Moth

D. Bevan and A. Paramanov report the results of an investigation to determine the correlation, if any, between the weight of female pupae of *Bupalus piniarius*, the pine looper, and the number of eggs laid by the adult moths. As a result a straight line regression was obtained for the "probable fecundity"/pupal weight relationship, "probable fecundity" being defined as the number of eggs laid plus the number of mature eggs found in the oviduct at death. The regression was $n=14.6w-63$, where n is the "probable fecundity", and w is the pupal weight in hundredths of a gram. Such a relationship makes it possible to estimate the fecundity of a generation of the pine looper moth merely by weighing a sample of the pupae.

Loss of Weight in Small Sized Hardwoods after Felling

During the spring and summer of 1955 an experiment was carried out in the Forest of Dean to determine the loss in weight due to drying of small unbarked spring-felled hardwoods when stacked in the forest for two months after felling. Stacks of oak, ash, beech, birch, sweet chestnut, sycamore and elm were weighed on the day of felling, and at fortnightly intervals from May to July. Comparisons were also made between the weight of bark in unseasoned and partially seasoned spring-felled oak.

The experiment will be repeated in 1956, and having regard to the vagaries of our climate it would be unwise to draw too general conclusions from the results of the limited work done hitherto. The most that can be said is that small-sized unpeeled hardwoods felled in May and stacked in open piles in the forest,

(1) lost up to 5 per cent of their fresh-felled weight one month after felling (a wet period);

(2) lost 5 to 10 per cent of their fresh-felled weight two months after felling (the weather becoming drier in the second month); and

(3) lost up to 20 per cent of their fresh-felled weight by the end of the summer (an exceptionally dry July, August, September).

Weight of fresh-felled oak bark, as a percentage of over-bark weight, was greater than weight of partially seasoned bark, as a percentage of partially seasoned over-bark weight, (10 weeks after felling).

PART I

Reports of Work carried out by Forestry Commission Research Staff

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES and G. BUSZEWICZ

232.31*

AS IN PREVIOUS YEARS the major part of the work of the Alice Holt Seed Testing Laboratory was devoted to routine tests on seed samples submitted for purity, germination and other analyses. During the year 680 samples were received, for which the following tests were completed:

Purity analyses	443
Germination tests by standard methods	1,068
Viability tests by the tetrazolium method	150
Moisture content tests	230

In addition to the above, over 100 germination tests were completed in connection with the experimental work described below.

The most difficult time in the seed testing year lies in March and April when considerable numbers of late samples are received, on which results are required urgently for seed sowing programmes. In order to provide a germination figure quickly, interim test reports are now issued within a few days of receipt of such samples, based on tetrazolium biochemical tests and on germination figures after five to seven days in a germinator. Interim reports are now prepared on all samples received after March 1st and later confirmed by the final test report.

The only major addition to the equipment of the Seed Laboratory was the installation of an automatic time switch to control the daily alternating temperature required in the seed germinators.

Seed Storage and Seed Longevity 232.315.2

The small constant temperature store at Alice Holt continued to be used for routine storage of seed lots required by Research Sections. The yearly turnover of seeds is about 250 lb. composed mainly of large numbers of small lots.

The construction of a new central refrigerated seed store for the Forestry Commission's seed may shortly be started at Alice Holt, and considerable time has been spent in drawing up recommendations of storage conditions and equipment and space requirements, to assist in the planning of this project.

A new procedure for despatching stored seed for sowing in nursery experiments was adopted during the year in order to reduce errors when seed is measured out in the field for sowing in experiment unit plots. Nearly all seed

* This and similar numbers refer to the Oxford System of Decimal Classification for Forestry.

for sowing in experiments was measured out and packeted in unit plot quantities prior to despatch to the sowing centres. During the period March-April, 1956, over 6,000 such units were packeted and despatched for sowing at different research nurseries.

Storage Conditions

The storage trial, started in 1950, using seeds of larch, pine and spruce, was continued into its sixth year. Results after four years' storage were presented in detail in *Rep. For. Res.* 1955, p. 15. Results after five years' storage showed little change in germination quality of Scots pine, Corsican pine, Sitka spruce and Norway spruce if stored dry in a sealed container at 36°F. Deterioration was rapid after the fourth year of storage in a sealed container at normal air temperature in an unheated room. These trials are now being extended to include *Tsuga*, Douglas fir, *Thuja* and *Abies* species, with particular attention to the moisture content of stored seed as well as to storage temperature.

Seed Pretreatment

Treatments to Increase Germination Rate 232.315.3

Pinus peuce has proved difficult to germinate both in the laboratory and in the field, as it exhibits dormancy thought to be caused by retarded evolution of the embryo and a hard impermeable seed coat. Investigation of pre-chilling, stratification and water soaking pretreatments for this species showed no appreciable improvement of germination with any treatment except stratification in moist peat at 36°F. for eight to twelve weeks. Given this pretreatment, 40 per cent of viable seeds germinated in a Copenhagen tank germinator, compared with nil germination of untreated seed. A study of methods of breaking dormancy of *Tilia platyphyllos* was started in collaboration with the International Seed Testing Association (I.S.T.A.) with the object of developing a more rapid method of laboratory germination test than exists at present. The results of stratification and acid seed treatments on germination are summarised in Table 1.

The Effect of Seed Stratification and Acid Pretreatment on the Germination of Lime, Tilia platyphyllos

Table 1

Pretreatment	Duration of Treatment (months)	Copenhagen Tank Germinator	
		Germination percentage	Live Ungerminated Seeds, percentage
Fruits stratified in moist peat @ 36° F.	2	1	91
	3	0	89
	4	1	93
	5	1	85
Extracted seed stratified in moist peat @ 36° F.	2	0	83
	3	3	80
	4	0	79
	5	1	83
Extracted seed soaked in concentrated sulphuric acid 15 minutes, and stratified in moist peat @ 36° F.	2	4	77
	3	27	47
	4	32	45
	5	57	25

The tetrazolium test indicated 94 per cent viable seed, while excised-embryo tests in a Copenhagen tank showed 78 per cent germination.

Stratification of fruit or seeds for periods up to five months has little effect, but acid pretreatment of extracted seeds followed by four to five months' stratification resulted in a substantial improvement in germinative power. However, large numbers of live seeds remained dormant even with this prolonged treatment.

Pretreatments to Protect Seed Against Vermin Attack

Preliminary tests with a range of animal repellent preparations applied as seed dressings for protection of seed against mice have been started. Laboratory trials are being carried out to assess the effects of treatments on germination as a supplement to field trials to study the evidence of damage by mice.

Seed Sampling

232.315.9

Trials were made to examine the accuracy of the present standard methods of seed sampling, by means of a sampling spear, from seed storage containers. The trials were restricted in the first instance to estimation of the sampling errors in mixed seed of known composition. Four 'populations' containing known amounts of artificially stained and unstained seeds were prepared in storage containers. Examination of samples removed by means of a sampling spear through the neck of the container, as for normal germination test samples, showed that there was no appreciable bias in the sampling procedure.

Seed Testing

Cone Examinations

232.318

Reports were issued on thirty-eight cone samples received from Conservancy collection areas during the year. A summary of progress in the use of a cone knife as a means of assisting estimation of likely seed yield is given on page 98.

Biochemical Tests

The study of the relationship between the results of biochemical tests using 2, 3, 5-triphenyl-tetrazolium bromide, other germination test methods, and field germination was continued on a reduced scale in 1955. The main effort was put into analysis and summary of the large volume of data collected in previous years' trials.

The tetrazolium test is considered a reliable emergency method and is now in regular use as a quick method for interim test reports. Assessment of seed viability during the test has normally been based on the staining reaction visible on the seed embryo. As reported last year, several workers consider that endosperm staining must also be considered, as assessment of viability based only on embryo staining may result in an overestimate of seed quality. Recent experiments with deliberately damaged seeds have failed to bring out any clear conclusions on the significance of endosperm staining. The results of many hundreds of tests based entirely on embryo staining classes have shown a consistently high correlation with the results of standard germination tests.

The tetrazolium test has been approved by the I.S.T.A. for use with very slow germinating tree species such as *Carpinus*, *Fraxinus*, *Prunus*, *Rosa* and *Tilia* until improved methods of actual germination test can be developed. This was the subject of some investigation, and it now seems possible that the excised embryo method of germination test may prove practical for some of these species, notably *Fraxinus*, *Tilia* and *Carpinus*.

Germination Tests

GERMINATION TESTS FOR SCOTS PINE AND NORWAY SPRUCE. An investigation of a number of methods of germination test for Scots pine and Norway spruce was carried out in collaboration with seven member countries of I.S.T.A. as a check on the suitability of the methods prescribed in the latest International Seed Testing Rules. The existing prescriptions were approved, and for both species it was concluded that the test should be completed at 21 days using a Copenhagen tank at an alternating temperature of 20-30°C. (68-86°F.).

GERMINATION TESTS FOR BEECH. Examination of germination test methods for beech seed led to the observation that the seed seems to require a fairly low temperature for rapid germination. Seeds appear to germinate more rapidly in the laboratory at temperatures of 35-40°F. (2-4°C.) than at the more usual germination test temperatures of 70-85°F. (20-30°C.). This observation is being followed up by further tests as beech is commonly slow to germinate under normal test conditions.

GERMINATION TESTS FOR LARCH. A summary of conclusions from routine tests on European, Japanese and hybrid larches is given on page 106.

X-Ray Tests

A series of tests was carried out in collaboration with the Swedish Forest Research Institute in Stockholm, to examine an X-ray method for rapid estimation of seed germination quality. The X-ray method, as developed in Stockholm, was compared directly with the results of Copenhagen tank tests and tetrazolium biochemical tests. These tests were carried out on the same lots of seed of Scots pine and Norway spruce, and were repeated on six samples of each species selected to cover a range of seed quality and seed age. The main conclusions were as follows:

(1) There was close agreement between estimates of germinative capacity using the Copenhagen tank method at Stockholm and at Alice Holt.

(2) The tetrazolium test provided a close estimate of seed germination quality as measured by the Copenhagen tank method.

(3) Direct comparison of the results of the X-ray method with Copenhagen tank, and tetrazolium methods, on identical seeds, indicated for both species that the X-ray test gave a considerable over-estimate of seed germination quality.

(4) There is evidence that the X-ray test gives reliable results only for fresh seeds.

Seed Moisture Content Tests

Preliminary investigations with a grain moisture hygrometer for rapid estimation of seed moisture content were completed. The instrument was calibrated for use with Scots pine, and gives accurate estimates for seed at levels of moisture content below 20 per cent. The instrument will be most valuable for checks on moisture content of seed in storage containers, and work is proceeding to calibrate the instrument for use with other species, including *Abies*, spruce, larch, Douglas fir and *Tsuga*.

In collaboration with the National Institute of Agricultural Engineering, an examination was made of a toluene distillation method compared with normal oven methods of moisture content determination for tree seeds. The toluene method was found to give accurate and quick results comparing closely with the results of the more prolonged oven methods.

Seed-Borne Fungi

Dr. S. Batko of the Pathology Section continued periodic observations on the occurrence of fungal infestation on seeds during the course of laboratory germination tests. The following new records of occurrence at Alice Holt were made during the year.

Acremoriella sp., on *Abies magnifica*

Aspergillus versicolor on *Lupinus nootkatensis*

Coniothyrium sp., on *Sarothamnus scoparius*

Fusarium culmorum on *Abies grandis*

Mycogone sp., on *Nothofagus procera*

Papulaspora sp. on *Abies* spp.

Pestalozzia hartigii on *Abies* and *Nothofagus*

It was not possible to re-open investigation of fungal control measures as had been hoped.

Other Activities

Collaboration in the work of the Biochemical Test and Forest Seeds Committees of I.S.T.A. was continued, and proposals for amendments to the International Seed Testing Rules relating to tree seeds were submitted for consideration at the 1956 I.S.T.A. Congress.

NURSERY INVESTIGATIONS

By R. FAULKNER and J. R. ALDHOUS

Partial Sterilisation

Time, Rate and Method of Applying Formalin 232.322.2

FORMALIN, when used for partial sterilisation of nursery soils, is normally applied as a drench, five gallons of formalin (38 per cent formaldehyde) diluted with 100-200 gallons of water being applied to every 100 square yards of nursery.

Large quantities of water have therefore to be handled and this handling may greatly increase the cost of the operation. An experiment was carried out in five nurseries in Scotland to see whether application of undiluted formalin as a spray would give a satisfactory degree of sterilisation. Concentrated spray applications at five gallons and ten gallons of formalin per 100 square yards of nursery bed, were compared with drench applications of the same quantities of formalin diluted with 100-200 gallons of water. Two dates of application were compared, namely in the autumn (end of October) and in spring (three to four weeks before sowing). Sitka spruce was the species sown in all the experiments. One set of experiments had to be abandoned owing to poor germination of seed. In another set no differential effects could be observed. In two nurseries (Fleet, Kirkcudbrightshire and Newton, Morayshire) the drench treatments produced much taller seedlings than the undiluted spray, and autumn treatments were considerably more effective than spring applications. In one of these nurseries there was a slightly greater yield in numbers of seedlings in the undiluted spray treatments. In the fifth nursery (Bush, Midlothian) there were no differences between the results from drench or undiluted spray treatments; but in this nursery alone the heavier (ten gallon) application gave better height growth and larger numbers of seedlings than the lighter (five gallon) application. These somewhat conflicting results suggest, on the whole that:

(*a*) Dilute drench applications of formalin are more effective than undiluted surface sprays;

(*b*) Applications in autumn are sometimes better than spring applications.

The experiment is being repeated to obtain further evidence.

Time and Rate of Application of Chloropicrin and Formalin

Chloropicrin, because it can be injected neat into the soil, thus avoiding the difficulty and cost of handling the large quantities of water required for formalin, is an attractive alternative means of partial soil sterilisation. Though chloropicrin is more than twice as expensive as formalin, the cost of sterilisation with formalin, after dilution and application, is not very different from the cost of sterilisation with chloropicrin. A final experiment in the series comparing chloropicrin and formalin as sterilising agents was carried out in five Scottish nurseries and one in Northern England in 1956. The experiment compared chloropicrin injected at four inches depth at three different rates, namely 0.315, 0.630 and 0.945 gallons per 100 square yards (15, 30 and 45 gallons per acre) with the standard formalin soil drench of five gallons of commercial formalin in 100 to 200 gallons of water per 100 square yards. The sterilising agents were applied in late October (autumn) mid December (winter) or thirty days before sowing (spring).

At one nursery the experiment was vitiated by poor germination of seed. At Wykeham (East Yorkshire), Newton and Inchnacardoch nurseries, the two highest concentrations of chloropicrin greatly improved the height growth of seedlings in comparison with formalin; but at Bush formalin produced much taller plants than the two lower concentrations of chloropicrin, and slightly taller plants than the highest concentration. At Fleet there were no significant differences between any of the treatments for height growth. Overall, it was found that taller plants were obtained by winter or autumn applications.

The effect on the yield of seedlings of either the sterilizing materials themselves. or the time of application, was negligible at all centres except Bush. At this nursery application of sterilizers thirty days before sowing caused a significant reduction in the seedling numbers when compared with applications in autumn.

From these results it appears that in most nurseries chloropicrin injected into the soil at a depth of four inches and at rates between 0.630 to 0.945 gallons per 100 square yards (30 to 45 gallons per acre), in late autumn, winter or up to thirty days before sowing, is generally a more effective way of sterilizing the nursery seedbed soil, from the point of view of producing taller seedlings, than 38 per cent formalin applied at five gallons per 100 square yards and diluted to approximately 100-200 gallons per 100 square yards.

This experiment concludes three years' work in Scotland on the effects of chloropicrin as a partial soil sterilization agent. These experiments have compared chloropicrin injected at various concentrations ranging from 0.21 to 1.43 gallons per 100 square yards (10 to 70 gallons per acre) with five or ten gallons of 38 per cent formalin diluted with 100 to 200 gallons of water per 100 square yards and applied as a soil drench. Comparisons have also been made of the effects of injecting chloropicrin at depths of three or five inches, and also of the effects of autumn, winter and spring applications. It has been shown that in general chloropicrin is superior to formalin in its sterilization effects when injected at four inches, at least 35 days before sowing, at a rate of 0.69 gallons per 100 square yards (35 gallons per acre). Formalin is a cheap chemical but expensive and difficult to apply when diluted, whereas chloropicrin is expensive but easy and cheap to apply. The total cost of materials and cost of application at the recommended rates is approximately the same for both materials.

In Southern England and Wales, a similar experiment comparing the effect on the growth of Sitka spruce seedlings of formalin applied as a drench or as a surface spray to the soil, or chloropicrin injected into the soil, was carried out in twelve Conservancy nurseries selected to cover a wide range of soil types.

The formalin was applied as a drench at the rate per 100 square yards of 3.3, 6.6 and 9.9 gallons of commercial 38 per cent formaldehyde solution in 100 to 200 gallons of water (150, 300, 450 mls. per sq. yd. in 1 to 2 galls. water per sq. yd.). As a spray, formalin was applied at the rate of 4.4 gallons per 100 square yards; this treatment was included because of the promising results obtained from the previous year's experiments.

Chloropicrin was applied at the rate of 0.7 gallons per 100 square yards (32 mls. per sq. yd.) at a depth of six inches in sixteen injections per square yard, distributed regularly.

Results showed that the formalin applied as a spray gave disappointingly little increase in growth. In the majority of nurseries formalin drench at the higher rates, and also chloropicrin, resulted in an appreciably or significantly increased height of seedlings. At Bramshill nursery (Hampshire) formalin had no significant effect on seedling growth, but chloropicrin caused a significantly increased mean height of seedlings. At Delamere (Cheshire) stocking and growth on all plots was unsatisfactory. This was attributed to difficulties in preparing beds in the spring when the ground was frozen. The cold weather of February and March, 1955, delayed application of the sterilants and so also the date of sowing. Thus the majority of trials were sown in the last week of April, but at Kinver (Staffs.), Ferndown (Dorset), and Pembrey (Carmarthenshire) plots were not sown until May.

In Scotland, large-scale "user" trials of chloropicrin injected by a tractor-drawn machine at a depth of four inches at the rate of 0.6 gallons per 100 square yards (30 gallons per acre) were successful in 1955; they are being repeated in 1956.

Residual Effects of Chloropicrin and Formalin

For the determination of residual sterilization effects, the 1954 chloropicrin and formalin experiment was resown with Sitka spruce seed without further sterilization treatments at Inchnacardoch, Newton, Fleet and Tulliallan nurseries. The original treatments were chloropicrin injections over the range of 0.21 to 1.43 gallons per 100 square yards (10 to 70 gallons per acre), applied ten, twenty or thirty days before sowing. In addition, 38 per cent formalin solution at ten gallons per square yard, suitably diluted with water, had been applied as a soil drench fourteen days before sowing.

At Fleet the previous year's chloropicrin treatments resulted in significant height increase in seedlings over the formalin treatment. At Wykeham chloropicrin at the highest rate produced the tallest plants, and in comparison with formalin only the two lowest levels of chloropicrin (0.21 and 0.51 gallons per 100 square yards) produced significantly smaller plants. At Inchnacardoch there were negligible height differences between sterilization treatments. At Newton, seedlings raised on previously formalin treated soil were much taller than seedlings raised on ground treated with chloropicrin at the three lowest rates, but similar in height to seedlings raised on soil treated with chloropicrin at the two higher rates.

No treatment had any appreciable effect on the yield of seedlings.

From the results it appears that the residual effects of formalin applied at ten gallons per 100 square yards are similar to those of chloropicrin injected at rates between approximately 0.8 to 1.14 gallons per 100 square yards.

Formalin, Chloropicrin and Shell CBP-55 Soil Sterilisers

A new experiment designed to compare the partial soil sterilising effects of formalin, chloropicrin and the new product Shell CBP-55 was sown with Sitka spruce at Benmore, Inchnacardoch and Tulliallan. At Tulliallan the results obtained followed the general pattern of the results at the other two nurseries, but due to low germination of seed no further mention of them will be made.

Formalin was applied at the standard rate of five gallons 38 per cent formalin per 100 square yards, diluted with 150 gallons of water, and applied as a soil drench. Chloropicrin was applied at 0.63 gallons per 100 square yards injected into the soil at a depth of four inches. Shell CBP was received as the emulsible concentrate, and was applied either undiluted by injection at a depth of four inches at rates of 1.24, 1.86 and 2.48 gallons per 100 square yards, or at similar rates emulsified with 100 gallons of water and applied as soil drench.

Table 2 shows the heights and numbers of seedlings at the two centres and from this it can be seen that CBP was superior to formalin at both centres. Chloropicrin was superior to CBP at Inchnacardoch but not at Benmore; and, rate for rate, injected CBP was the most successful method of application at Benmore, whereas the reverse was true at Inchnacardoch. Seedling yields were generally higher on CBP treated ground.

Height growth and yield of one year Sitka spruce seedlings raised on unsterilized soil and on soil treated with formalin, chloropicrin, and CBP-55

Table 2

Treatment	Mean Height (ins.)		Numbers per sq. ft.	
	Inchnacardoch	Benmore	Inchnacardoch	Benmore
No sterilisation	1.82	1.92	91	68
5 galls. 38% formalin in 150 gals. water per 100 sq. yds.	2.26	2.19	98	61
0.63 galls. chloropicrin per 100 sq. yds.	2.93	2.54	96	73
4.38 Kgm. CBP-55 per 100 sq. yds. (injected)	2.31	2.37	100	63
5.57 do. do. do. do.	2.42	2.47	98	66
8.76 do. do. do. do.	2.43	2.77	98	69
4.38 Kgm. CBP-55 do. do. *emulsified with* 100 *gals. water*	2.49	2.37	110	75
5.57 do. do. do. do.	2.67	2.46	105	76
8.76 do. do. do. do.	2.60	2.45	104	73
Standard Error ±	0.08	0.07	3	3
Difference necessary for significance 5%	0.24	0.22	9	8
1%	0.32	0.30	Not Sigt.	11

Nursery Manuring

Rates of Application of Potash and Phosphate Fertilisers 232.322.41

In recent years seedbed applications of nitrogen, potash and phosphate manures in experiments in Scotland have been standardised at rates equivalent to 0.25 oz. N and 0.40 oz. per square yard each of K_2O and P_2O_5. These rates have given satisfactory growth rates of seedlings, but little is known of the effects of much higher rates. For this reason an experiment giving a factorial combination of P and K fertilisers at normal, twice and three times the normal rates, and of N at normal and twice the normal rates, was sown with Sitka spruce in order to determine their single or combined effects on seedling growth. The experiment was repeated at six nurseries.

At two of the nurseries the experiment was abandoned on account of poor germination of the seed. In the remaining nurseries the effect of the increased rates of nitrogen and potash was not significant; but at Newton, Bush and Wykeham the higher rates of phosphate produced much taller seedlings, the difference being significant at Wykeham and highly significant at Bush and Newton.

No treatment had any significant effect on total seedling numbers and there were no significant interactions between any two treatments for either heights or numbers at any of the centres.

The overall growing season was generally dry and this may have limited growth responses. For this reason the experiment is being repeated again in 1956.

Times and Rate of applying Nitrochalk to Seedbeds of Scots pine, Japanese larch and Douglas fir

In view of the widespread belief that summer top-dressings of nitrogen increase the risk of frost damage to larch and Douglas fir by delaying hardening-off, and also that June applications of "Nitrochalk" at 5 lb. per 100 square yards produce adequately large seedlings for lining out, a new series of experiments was started to compare the effects of three rates of nitrogen. Scots pine, Japanese larch and Douglas fir were used as test species. The experiment compared June, July and August applications of 'Nitrochalk' applied as two equal top dressings totalling five, ten and fifteen lb. per 100 square yards (five lb. is the usually recommended rate for these three species).

At most nurseries there were long periods of drought during the summer, and therefore although "Nitrochalk" applications were made as specified, in many cases the fertilizers remained on the soil surface for many weeks before being washed into the soil. For this reason data on the time of application cannot be regarded as reliable.

Scots pine was used at Inchnacardoch, Tulliallan and Wykeham. At Wykeham significantly taller seedlings were obtained by June applications when compared with July and August applications; and the heaviest rate of application produced taller seedlings than either of the lower rates. At Tulliallan the date of application had negligible effect on seedling heights, and, unexpectedly, the five and fifteen lb. per 100 square yard treatments produced seedlings which were significantly taller than those raised with ten lb. per 100 square yards. At Inchnacardoch none of the treatments produced any differences in seedling heights. At no nursery were seedling numbers affected.

Japanese larch was used at Newton, Wauchope and Benmore, but at Benmore the experiment was abandoned on account of poor germination of the seed. At Wauchope both the July and August applications produced significantly taller seedlings than the June applications, whereas at Newton the complete reverse was the case. Rates of application did not significantly affect the final seedling heights at either centre. Total numbers were highly significantly less, following the June applications at Wauchope, and increasing amounts of "Nitrochalk" were followed by corresponding reductions in seedling numbers. No treatment affected the yield of seedlings at Newton.

Douglas fir at Benmore responded most of all to the August application of "Nitrochalk", and the difference in height when compared with June applications was highly significant. The rate of application did not affect height growth. At Fleet neither the time or rate of application produced any great variation in seedling heights.

Frost damage of Douglas fir occurred at Fleet, and it is interesting to note that demonstration plots of seedlings which received no "Nitrochalk" were, according to visual assessments, more severely damaged than any of the plots receiving nitrogen.

From these results it appears that in 1955, which was an abnormally dry growing season, Douglas fir and Japanese larch were unresponsive to manuring with "Nitrochalk" at rates up to three times larger than those usually given. Higher rates of "Nitrochalk", of fifteen lb. per 100 square yards, produced taller Scots pine seedlings at two out of three nurseries. Data on the time of application of "Nitrochalk" was unreliable due to the long periods of drought which took place after some of the applications. The experiment will be repeated in 1956 in order to obtain more data on the subject.

In the south, a similar experiment was carried out, again to provide data for the manuring of Japanese larch and Douglas fir, for which at present lower dressings of nitrogen are recommended than for Sitka spruce and most other conifers. Both nitrochalk and ammonium sulphate were tested, each at one-third, two-thirds, and the full rate prescribed for Sitka spruce, and applied in mid-June, mid-July or mid-August. The experiments were done at Kennington nursery near Oxford, Wareham nursery (Dorset) and Bramshill nursery (Hampshire).

Results from all three nurseries show surprisingly little difference in growth of seedlings given the various treatments. At Wareham, the Japanese larch given a dressing of nitrogen in mid-June were significantly taller than seedlings given nitrogen later. This was the only significant difference that appeared. That differences in growth were small can be attributed to the dry weather experienced at each nursery from early July to the end of August.

A sharp frost occurred in each nursery in mid-October. Assessments of seedlings damaged by this frost showed that there was no difference in frost susceptibility of seedlings in any treatment.

These experiments will be repeated.

Sterilization, Hopwaste and Lime Applications (232.322.2 and 232.322.41)

In two of the main sections at Newton nursery, where a general decline in the growth of conifers has been observed during the past ten years, it was decided to test the response of both Scots pine and Japanese larch to formalin partial soil sterilization, hopwaste additions, and lime (applied purely as a manure and not as a means of radically altering the soil pH value). All three of these treatments had been suggested as possible remedies, and a soil analysis showed that the organic content was low (4 to 5 per cent) on both sites, and that the lime content was on the low side in one section but satisfactory on the other. The ground in both cases had been used for nursery purposes for many years, and was therefore likely to benefit from partial soil sterilization.

The experiment consisted of factorial combinations of a formalin drench treatment at standard rates, hopwaste application at approximately 8 cwt. per 100 square yards, and ground mineral limestone applied at 17.3 lb. per 100 square yards (7.5 cwt. per acre) in 1955. A second similar dressing of limestone will be applied to half the plots in 1956. The whole experiment received N, P & K fertilizers at standard rates.

The results showed very definite growth responses to sterilization and hopwaste treatments by both the Scots pine and Japanese larch at each site; a slight response to lime was recorded on the Japanese larch at one of the sites. More definite information will be available on the effects of the lime in 1956 after the material has had a longer period in which to react in the soil.

Effects on Silver Fir Seedlings of soil sterilization, Nitrogen, Phosphate and Potash

Using *Abies grandis* as test species at Benmore, and *Abies procera* at Tulliallan and Inchnacardoch, experiments were carried out to find the response of these two species to partial soil sterilization, nitrogen, and combined phosphate and potash fertilizers. The partial soil sterilization was carried out with formalin (5 gal. of 38 per cent formalin in 150 gal. of water per 100 square yards). Nitrogen was given as two top dressings of "Nitrochalk" in July totalling approximately 10 lb. per 100 square yards (0.25 oz. N per square yard). Potash as sulphate of potash at 5.21 lb. per 100 square yards (0.40 K_2O per square yard), and phosphate as super-phosphate at 13.88 lb. per square yard (0.40 oz. P_2O_5 per square yard), were both cultivated on to the surface layers of the seedbeds two to three weeks before sowing.

At all nurseries the sterilization treatment produced a small but highly significant height increase, but the N, P & K fertilizers had no significant effects on heights at any of the nurseries.

None of the treatments had much effect upon the yield of seedlings.

These results broadly confirm results obtained at two nurseries in 1954.

Long-term Fertility Demonstrations

The Nursery Nutrition Advisory Sub-Committee's long-term fertility demonstration at Teindland woodland nursery, Moray, was continued into its sixth year, and was sown, as in the past, with Sitka spruce and lodgepole pine. Main treatments are artificial fertilizers only, hopwaste only, and combinations of the two.

Results (*see* Table 3) show that in the Sitka spruce section there are no significant differences between the three manurial treatments. This is contrary to the 1953 and 1954 results when the combination of hopwaste and artificials was the outstanding treatment. None of the treatments had any significant effect on the yield of seedlings.

In the lodgepole pine section the 1954 results were confirmed. These showed that hopwaste and artificials in combination and hopwaste alone produced much taller seedlings than artificials alone. No treatment affected seedling numbers significantly.

Teindland Woodland Nursery Fertility Demonstration: End of Sixth Year Height and Number Production Figures for Sitka spruce and Lodgepole pine one-year seedlings, 1955

Table 3

Treatment	Sitka spruce			Lodgepole pine		
	Mean Hts. in ins.	Numbers per sq. ft.	% over 1½ ins. tall	Mean Hts. in ins.	Numbers per sq. ft.	% over 1½ ins. tall
No manures or hop-waste	1.42	89	34	1.40	61	37
Artificial fertilizers only	2.25	81	82	1.56	63	41
Hopwaste only	2.31	70	88	2.16	59	77
Artificial fertilizers and hopwaste	2.15	74	78	2.20	63	79
Standard Error ±....	0.07	4.4	—	0.10	2.4	—
Difference for 5% significance: 1%	0.27 0.41	Not Sigt.	— —	0.34 0.52	Not Sigt.	— —

The Newton and Fleet long-term demonstrations continued into their fourth and third years respectively. At Newton the whole area was under transplants and was not assessed. At Fleet the first crop of Sitka spruce was allowed to grow for a second year. The tallest plants were produced on sterilized ground, and as would be expected in the first rotation, differences in mean heights between the various manurial and cropping treatments were only slight.

In the south, the trial at Elvetham Nursery, Bramshill, of the long-term effect on growth and yield of Sitka spruce seedlings of three regimes of manuring, was continued into its sixth year. Results appear in Table 4.

Height growth of seedlings, though poor, was slightly better than in the preceding year.

Manuring Trial at Elvetham Nursery, Bramshill:
Yield of Seedlings, 1955

Table 4

Treatment	Mean Height (inches)	Nos. (thousands) per 100 sq. yds.	Nos. (thousands) Usable per 100 sq. yds.
No organic or inorganic fertilizer	0.49	66.1	0.3
Inorganic N P K fertilizer	1.22	64.3	12.3
Bracken and hops compost	1.41	51.0	17.2
Compost and fertilizer	1.38	58.9	18.2
Differences for significance: 5%	0.12	11.7	—
1%	0.17	16.9	—

Compost led to significantly lower numbers of seedlings compared with fertilizer, but significantly increased their height.

At Wareham, the demonstration of fertility maintenance following regimes prescribed by the late Dr. M. C. Rayner continued for the second year in its new form. Growth of plants in both sections was good, but not as good as in previous seasons. There was no difference in growth or yield of seedlings or transplants whether on ground manured with a bracken/hops compost or a pure hops compost. Late in the season, slight discolorations symptomatic of potassium deficiency appeared in several crops on ground manured with pure hops compost. These symptoms appeared later and to a lesser extent than in the previous year.

Magnesium Manuring

An experiment was carried out at Thornhill nursery, Savernake, in which magnesium sulphate applied as Kieserite ($MgSO_4.H_2O$) was applied at the rates of two, four and eight lb. per 100 square yards (9, 18 and 36 grams per square yard). In the previous year, seedlings in a previous experiment on the same site had shown marked symptoms of magnesium deficiency.

In this experiment, no differences in seedling growth or numbers were found. However, a distinct difference in colour became apparent in late summer and remained throughout the winter. Seedlings on plots with the heaviest dressing of magnesium were then normal green colour, whereas seedlings on the controls were yellow-green. Seedlings on plots which had received Kieserite at four lb. per 100 square yards were intermediate in colour.

This experiment will be left to grow on for another year.

Charcoal as a Soil Improver in Forest Nurseries 232.322.5

Experiments in which a two-inch layer of charcoal was incorporated into the top six to seven inches of the soil were carried out at Tair Onen and Ddwilig (St. Asaph) nurseries, both of which have abnormally heavy soils. The object of the experiments was to test the effect of charcoal on growth of conifer seedlings and on soil workability.

Four species were sown at each nursery, namely Japanese larch, Sitka spruce, Corsican pine and birch. In both places the Corsican pine and birch failed to produce a satisfactory crop. There was little difference in seedling numbers between treated and untreated plots, but heights of Japanese larch and Sitka spruce seedlings were appreciably or significantly lower on plots treated with charcoal.

The ground treated with charcoal was more friable and weeds were extracted with less disturbance. At Tair Onen the time taken to weed the plots treated with charcoal was less than half that of the controls. This can be attributed partially to the easier weeding already mentioned, but more to the fact that the control plots carried a more numerous weed crop.

At Ddwilig, it was observed that snow remained longer on plots treated with charcoal than on the control or on surrounding ground.

Both experimental areas will be resown.

Use of Krilium to Improve Soil Texture 232.322.5

The seedbed areas at Ddwilig (St. Asaph) Nursery, which in 1952 and 1953 had been treated with 'Krilium' soil conditioner, were resown in 1955 with five species of conifer. There were no significant differences in the height or numbers of seedlings at the end of season, nor were there any consistent differences in the texture of the soil between treated and untreated plots. This experiment will now be closed.

Date of Sowing 232.323.3

An experiment to test the effect of date of sowing on seedling numbers and growth was repeated at Kennington Nursery (see Table 5).

Date of Sowing Experiment, Kennington
Yield of Seedlings, 1955
Table 5 *Sitka spruce*

Date of Sowing	Nos. (thousands) per 100 sq. yds.	Average Ht. (Inches)	% Usable (Over 1½ inch)	Nos. (thousands) Usable Per 100 sq. yds.
March 14th	98.6	1.65	48	47.1
March 31st	116.5	1.51	43	49.1
April 15th....	135.3	1.64	51	68.4
April 30th....	133.7	1.52	40	53.0
May 16th	144.6	1.26	20	29.3
Differences for 5%	21.8	0.14	—	—
significance: 1%	30.2	0.19	—	—

Although the number of seedlings increased progressively, and was highest on plots sown in mid-May, it will be seen that highest productivity was obtained from the sowing in mid-April. This peak of productivity is later than in most years, and is attributed to the cold, dry weather experienced in April. This delayed the germination of plots sown early, and was followed by warm rainy weather which encouraged quick germination of the latest sown plots.

This experiment will be repeated annually as long as there is a substantial programme of experiments in which Sitka spruce is sown.

A comparison was also made of the accuracy of information obtained from bands 3 inches by 36 inches sown at the same density as for broadcast beds, and assessed completely, with that obtained from the standard sampling assessment made on broadcast plots three feet square. (The sample consists of five strips 2 inches by 36 inches for end of season assessments of plant numbers, and three strips 2 inches by 36 inches for end of season assessments of height.)

It was found that there was a loss of precision of about 15 per cent if one band only was assessed compared with the results from four bands. Full assessments of four bands gave slightly more precision than was obtained from the standard sample of broadcast beds.

Seedbed Covering Materials

Depth of Cover 232.323.5.

An experiment comparing the effect on germination and growth, of Sitka spruce and *Tsuga heterophylla*, of four thicknesses of grit covering, ranging from $\frac{1}{8}$ in. to $\frac{1}{2}$ in., was carried out at Kennington Nursery, and repeated at Ampthill and Wareham. Results showed that, taking the three nurseries together, for Sitka spruce, a covering of about $\frac{3}{16}$ in. thick gave best results, while for *Tsuga* a covering about $\frac{1}{4}$ in. thick was best. The *Tsuga* crop on plots with $\frac{1}{2}$ in. covering at Ampthill failed, and the other crops were poor. (see Table 6).

Depth of Cover Experiments, 1955:
Total Numbers of Seedlings Per 100 *Square Yards (Thousands) and Average Height (Inches)*

Table 6

Thickness of Cover in inches	Wareham		Kennington		Ampthill	
	No.	Ht.	No.	Ht.	No.	Ht.
			Sitka spruce			
$\frac{1}{8}$	105.7	1.44	140.8	1.60	85.0	0.83
$\frac{3}{16}$	121.5	1.52	148.4	1.58	109.0	0.85
$\frac{1}{4}$	169.6	1.50	116.7	1.60	88.8	0.81
$\frac{1}{2}$	105.6	1.30	54.7	1.60	43.3	0.81
			Tsuga heterophylla			
$\frac{1}{8}$	54.9	1.04	66.6	0.96	4.2	0.59
$\frac{3}{16}$	72.4	0.93	120.5	0.87	12.2	0.49
$\frac{1}{4}$	81.3	1.02	143.1	0.91	17.0	0.49
$\frac{1}{2}$	51.3	0.93	57.5	0.71	0.6	0.43

For numbers, the differences for significance have not been given because they have been calculated using a transformation. However, in each nursery the differences shown were significant or very significant.

Tsuga seedlings on plots with half an inch of grit were significantly or appreciably smaller at all nurseries, and so were Sitka seedlings on plots with half an inch of grit at Wareham. Other differences in height were not significant.

These experiments will be repeated.

Colour and Grade of Covering Material

An experiment was carried out at Kennington Nursery in which the effect of colour and particle size of the grit cover on seedling germination and growth was compared. Three materials were used; they came from St. Austell, Cornwall, Penmaenmawr, North Wales, and Clee Hill, and in colour were off-white, grey, and black, respectively. Each material was graded by sieving into the following grades: (i) 0.2 mm.-2 mm.;(ii) 2 mm. to 6 mm. (¼ inch); (iii) over 6 mm. (¼ inch).

Lawson cypress and Sitka spruce were sown.

Moderate to full crops of Sitka spruce and Lawson cypress were obtained from plots covered with all grades of St. Austell grit. Plots covered with the fine grades of both Penmaenmawr and Clee Hill grits carried poor crops but plots covered with the medium and coarse grades of both materials carried crops little inferior to plots covered with St. Austell grit.

Maximum and recording thermometers were placed on the ground, and just covered with grit so that the bulbs were not exposed to the sun. The highest temperatures occurred in mid-July, when temperatures exceeding 100°F. were recorded. Temperatures under the darkest cover were up to ten degrees higher than under the light cover, the differences being greater the higher the temperature. A maximum temperature of 119°F. recorded under the Clee Hill grit occurred on July 17th. The temperature under the St. Austell grit on the same day was 111°F. Maximum temperatures exceeding 110°F were recorded under the Clee Hill grit on thirteen other occasions. The experiment will be repeated.

Seedbed Covering Material for Abies species

In Scotland, the 1954 experiment, comparing soil and grit covers at depths of 0.25, 0.5 and 0.75 inches over *Abies* seed, was repeated at Benmore using *Abies procera* as test species, and at Bush and Fleet nurseries using *Abies lowiana.*

Results varied considerably between nurseries. At Benmore the half-inch cover produced the greatest yield of seedlings, and grit cover produced far more seedlings than soil cover. No treatment had any significant effect on seedling heights. The highest yield of seedlings at Bush nursery was obtained with the three-quarter inch cover, the quarter-inch depth produced a very low yield indeed. Grit cover produced slightly more than twice the yield of seedlings compared with soil cover, and grit also appreciably increased the mean heights of seedlings. The depth of cover did not significantly affect height growth.

Covering material did not affect seedling yields at Fleet, but the soil cover caused an increase in heights when compared with grit. Both the quarter-inch and half-inch covers produced a much greater yield of seedlings than the three-quarter inch depth cover. The experiment is being repeated for a third year in order to obtain more conclusive evidence.

Irrigation of Seedbeds 232.325.1.

The large-scale trial of watering by an overhead sprayline was repeated at Kinver nursery for the third year. Sufficient water was applied when the soil moisture deficit exceeded 0.5 inches to bring the deficit down to zero.

The summer months were dry and irrigation was applied on twelve occasions.

Seedlings (Sitka spruce) responded greatly to irrigation in height growth, but their survival was not significantly affected. See Table 7.

Irrigation Experiment, Kinver:
Yield of Seedlings, 1955
Table 7 *Sitka Spruce*

Treatment	Ht. (inches)	Thousands per 100 sq. yds.
Irrigated	4.0	124.2
Control	2.7	131.4

A number of tensiometers were installed in the experimental area by Dr. A. J Rutter. These instruments showed that the watering regime successfully sustained the water supply to the plants. The experiment will be repeated.

Weed Control in Nurseries 232.325.24

Weed Control With Mineral Oils Applied Before Seedling Germination

Three small experiments were carried out at Kennington, Bramshill and Wareham, comparing the effect on growth and yield of Sitka spruce seedlings of a new vaporising oil marketed by the Shell Petroleum Company under the name 'Shellspark', and replacing their previous form of vaporising oil (T.V.O.). In all nurseries there were no significant differences in the weed control and yield of seedlings between plots treated with T.V.O. and plots treated with 'Shellspark' at the standard rate. (1¼ gallons per 100 square yards or 60 gallons per acre).

Weed Control With Chemical Applied Before Seedling Germination

At Bramshill, an experiment was carried out comparing the effect on growth and yield of Sitka spruce and Douglas fir seedlings of:

(1) C.M.U. (3, P-chloro-1, 1 dimethyl urea) applied at the rate of 1¾, 3½ and 7 ounces per 100 square yards, (½, 1, 2 grams per square yard) 2-3 days before sowing,

(2) T.C.A. (Sodium trichloracetate) applied at the rate of 1.1, 2.2 and 4.4 lb. per 100 square yards (5, 10, 20 grams per square yard) 2-3 days before seedling emergence.

(3) C.I.P.C. (m-chloro isopropyl-N phenyl carbamate) applied at the rate of 0.55, 1.1 and 2.2 lb. per 100 square yards (2½, 5 and 10 grams per square yard) 2-3 days before seedling emergence.

(4) Control treatment—vaporising oil at 1¼ gallons per 100 square yards (60 ml. per square yard or 60 gallons per acre) applied 2-3 days before seedlings germinate (i.e. a pre-emergence application).

As previous work had indicated that Douglas fir transplants were more tolerant of C.M.U. than other species, Douglas fir seed was sown to see whether the young seedlings were also tolerant.

On control plots, germination and growth of Douglas fir was moderate and that of Sitka spruce good. On all plots treated with C.M.U., and on plots with the higher rates of T.C.A., no seedlings of either species germinated; only a few seedlings germinated on plots receiving the lowest rate of T.C.A. and on plots receiving C.I.P.C. sprays. Weed growth on treated plots was slight.

At Kennington and Ampthill, experiments were carried out testing the effect of two oils fortified with pentachlorphenol, 'Sprex', and RD 4194, on the growth and yield of Sitka spruce seedlings and on growth of weeds. Both materials were applied four days before sowing, four days after sowing, and three days before seedling emergence, Sprex being applied at the rate of 1/24, 1/12 and ⅛ gallons per 100 square yards (2, 4 and 6 ml. per square yard or 2, 4 and 6 gallons per acre) and RD 4194 being applied at 1/3, 2/3 and 1 oz. active ingredient per 100 square yards (0.1, 0.2 and 0.3 gm. per sq. yd. or 1, 2 and 3 lb. per acre).

At both nurseries vaporising oil combined best control of the weed crop with least damage to seedlings. Sprex did little damage to the seedling crop, but did not control weeds as well as vaporising oil, while RD 4194 gave adequate control of weeds but, especially in the heaviest rate of application and the latest date, very significantly reduced the numbers of seedlings. See Table 8.

Chemicals for Weed Control:
Seedling Numbers (thousands) and Weeding Times per 100 *sq. yds.*
at Ampthill Nursery, 1955. (*Mean of rates of application*)

Table 8 *Sitka spruce*

Treatment	Nos. in thousands	Weeding Times Hrs.	Mins.
Pre-emergence Control (Vaporising oil)	103.1	6	30
Sprex pre-sowing	99.6	21	40
„ post-sowing	63.6	30	—
„ pre-emergence	53.8	15	—
RD 4194 pre-sowing	52.1	11	40
„ post-sowing	40.5	8	20
„ pre-emergence	14.7	5	—

Post-emergence Control of Weeds with Mineral Oils

An experiment was carried out at Kennington Nursery testing the effect of sprays of Shell weedkiller 'W', applied at intervals of three weeks, commencing six and nine weeks after first germination of seedlings of Lawson cypress and *Tsuga heterophylla* at the rate of 0.31, 0.41 and 0.62 gallons per 100 square yards (15, 20 and 30 ml. per square yard, or 15, 20 and 30 gallons per acre).

The earlier spraying at the two heavier rates appreciably reduced heights and numbers of *Tsuga* and Lawson seedlings. All applications of weedkiller treatments, commencing nine weeks after germination, had no effect on the growth or yield of either species.

An experiment was carried out at Bramshill Nursery testing the effect of the butyric homologues of M.C.P.A. and 2, 4-D. These homologues have been shown to have no growth regulating effect themselves, but can be assimilated by the plant, and in certain cases broken down to the active hormone. When this occurs the plant is killed. A number of weeds were known to be susceptible to this form of weedkiller, but nothing was known of the response by conifer species. This experiment was to test whether Japanese larch and Corsican pine could break down either material to its active form. Results showed that all rates of application, from $\frac{1}{6}$ oz. to $1\frac{1}{3}$ oz. active ingredient per 100 sq. yd. ($\frac{1}{2}$-4 gm. per sq. yd. or $\frac{1}{2}$-4 lb. per acre) damaged both species and only killed broad-leaved weeds.

Two new weedkilling materials which had shown promise in the United States were tested in an experiment at Bramshill. These materials, C.D.A.A. (alpha-chloro-N, N-diallyl acetamide) and C.D.E.C. (2-chloroallyl-diethyl-dithio carbamate) were applied as pre-sowing (2 to 3 days before sowing), pre-emergence (2 to 3 days before seedling emergence) or post-emergence (ten weeks after first germination) treatments.

Each material was applied as a spray at the rate of $1\frac{1}{3}$, $2\frac{2}{3}$ and 4 oz. active ingredient per 100 square yards in a 0.8% solution. (0.4-0.8 and 1.2 gm. per sq. yd. or 4, 8 and 12 lb. per acre). There were two control treatments, hand-weeding and vaporising oil pre-emergence spray. Both materials significantly or appreciably reduced numbers of seedlings except when applied before sowing. C.D.A.A. more effectively controlled weeds than C.D.E.C. Results from the pre-sowing applications of both materials are sufficiently promising to warrant further trials.

Undercutting of Seedbeds 232.326.2

At Fleet, assessments were made on Scots pine plants lifted from the 1954 undercutting experiment. The plants had been raised in broadcast beds at densities of 16, 32 and 48 per square foot and undercut at depths of two, four or six inches in August the first year, or March, April, June, July or September in the second year. From the assessments of shoot length and weight, root weight, numbers of thickened secondary roots over two inches long, and root collar diameters, it was shown that the shoot length is reduced by undercutting in August, March or April when compared with undercutting in June, July or September. Only the September treatment produced appreciable differences in root numbers and root weights; in both cases a reduction was recorded.

The depth of cutting only affected root numbers, and the deeper the cut the more rootlets over two inches long were recorded.

The main effect of sowing at lower densities than normal was to cause increases in root collar diameters, root numbers and root weights.

These results largely confirm the findings reported last year.

An experiment on undercutting oak seedlings was lifted and assessed at Bush nursery. In this experiment only one sowing density was used and because of poor germination of the seed resulted in only six plants per square foot. Nevertheless, undercutting at four inches decreased the rootlet numbers and decreased root weights when compared with cutting at six inches. As at Fleet, undercutting in March or April reduced shoot lengths in comparison with other months of undercutting, and undercutting from March to July produced much greater numbers of secondary roots than undercutting in August of the first year. The root weight was also greatly increased after the same treatments.

From this first-year work on oak, it appears that August of the first year is not a suitable time for undercutting; but undercutting in spring or early summer in the second year, at a depth of either four or six inches produces a suitable fibrous rooted plant which in appearance compares quite favourably with a transplant.

Summer Shading of Seedbeds 232.327.1

An experiment was carried out at Tair Onen nursery (Glamorgan) comparing growth and yield of seedlings on shaded and unshaded seedbeds. The shaded seedbeds were arranged in blocks of eight beds thirty-two feet long. Six species were sown:—Japanese larch, Douglas fir, Norway spruce, *Pinus contorta* and an *Abies* sp.

The seedbeds were covered with lath shelter whenever the maximum screen temperature had exceeded 70°F. for two consecutive days. As the summer was hot and dry, the treated beds were covered for most of July and August and part of June and September.

At the end-of-season assessment no significant differences could be found between growth and yield of seedlings on shaded and unshaded beds.

During the time the beds were covered, the maximum and minimum temperatures and the humidity were recorded under the shelter and in the open. The maximum temperature in the open was 0-2°F. higher than under the shelter, and the minimum was 1-3°F. lower. The relative humidity was usually but not always two or three per cent higher under the shelters than in the open.

Control of Cutworm 232.327.4

An experiment was carried out at Kennington Nursery to test the phytotoxicity of various insecticides which might be required in forest nurseries, and to give preliminary indications of materials which might control cutworm (*Agrotis* sp.). This pest has been causing appreciable damage in the nursery.

B.H.C., D.D.T., and Aldrin were applied both as sprays and dusts at the highest rates which are likely to be recommended for control of insect pests; in addition Dieldrin was applied as a spray and Aldrin, Dieldrin and Paris green were put down in bran bait.

Each material was applied before sowing, at the time when the parent moth lays her eggs, and at time of first visible damage.

Assessments made at the end of the growing season showed that none of the materials had any harmful effects on growth of Sitka spruce seedlings. An appreciable amount of damage by cutworm had occurred in the experiment, but because the plots had not been isolated it was impossible to say whether damage found on one plot was caused by larvae resident in the plot or by others moving in from adjacent plots.

Maleic Hydrazide as a Growth Inhibitor 232.329.9

Work was continued at Newton and Benmore, using much higher concentrations of maleic hydrazide than in previous experiments. This was decided in view of the fact that the lower concentrations of maleic hydrazide used in the past had produced negligible effects on treated seedlings.

The object of the experiment was to determine whether maleic hydrazide will retard flushing and/or inhibit growth of conifer seedlings when applied in dilute solution as a foliar spray. The treatments selected were sprays of 0.145, 0.290, 0.434 and 0.580 per cent solutions of maleic hydrazide in water. Scots pine, lodgepole pine, Corsican pine and Douglas fir one year seedlings were treated at Newton; and lodgepole pine, Japanese larch and Norway spruce one year seedlings were treated at Benmore. The liquids were applied as foliar sprays to all species, other than larch, at the time when the terminal buds started to swell. Larch was sprayed shortly after flushing.

An assessment of the effect of maleic hydrazide on the speed of flushing, which was carried out at Benmore only, clearly showed that increasing concentrations of maleic hydrazide cause a progressive decrease in the speed of flushing of Norway spruce and lodgepole pine.

Increasing concentrations of maleic hydrazide over the range of solutions tested produced correspondingly smaller seedlings for all species at both nurseries. None of the treatments caused any pronounced or significant reductions in seedling numbers at Newton, but at Benmore the number of seedlings of Norway spruce was drastically reduced by the higher rates of application. Slight but significant decreases in numbers occurred in the Japanese larch treated plots, the higher rates causing the most serious losses.

Maleic hydrazide not only stunts shoot growth, but also needle length and root development (determined by weight) and in many cases causes severe foliage scorch. For this reason seedlings from all these trials are to be lined out for further observation.

Handling and Storage of Plants 232.412.4

An experiment was carried out at Alice Holt comparing the survival and moisture content of bundles of transplants wrapped or protected and exposed for a period of ten or twenty days. Treatments selected are those which might be suitable for large scale use in handling and transport of plants.

Materials used were:

(1) an emulsion of polyvinyl resin which on drying is said to leave a thin film and form a moisture barrier, thus preventing desiccation.

(2) Sisalkraft paper.

(3) Polythene sheet.

(4) Straw and moss.

These materials were applied to either roots alone, or to both root and shoot. After exposure, part of each bundle of transplants was lined out, and the remainder dried for determination of the wet/dry weight ratio.

Assessments at the end of the season showed that plants wrapped completely in polythene had withstood the longer period of exposure without loss. A few of the plants wrapped in paper or in straw and moss had survived the longer period of exposure, but the remainder exposed for the longer period had died. Most plants survived the shorter period of exposure; however, survival was lowest (about 50 per cent) in plants protected with the polyvinyl resin emulsion and in control (untreated) plants.

A graph plotting the moisture content against survival showed a very clear relationship. Where the moisture content (fresh weight: dry weight as a percentage of dry weight) exceeded 80 per cent, survival was over 90 per cent; where it was below 30 per cent, survival was nil. Between these values, survival was proportional to the moisture content.

PROBLEMS IN AFFORESTATION

By M. V. EDWARDS and G. D. HOLMES

Age and Type of Planting Stock 232.411.2

A SERIES of intensive experiments was planted at six forests in England and Wales in 1955 and 1956, to examine the forest performance of several types of planting stock of Sitka spruce raised by the best known nursery manurial treatments. The experiments consist of a factorial test of age and type of plant, including first year seedling (1+0), one-plus-one transplants (1+1), two-plus-one transplants (2+1), and two-plus two transplants (2+2). Other factors to be compared are nursery origin (comparing plants raised in heathland and established nurseries); size class of plant; depth of planting; and the position of planting on ploughed ground. There have been many experiments on these topics in the past, but most of the experiments were carried out some years ago with methods of ground preparation now superseded by modern ploughing techniques, and it is doubtful whether the conclusions from these experiments can be applied today.

Mechanical Planting 232.429

Preliminary trials have been carried out with the 'Lowther' Planting Machine mounted on the toolbar of a 'County' tractor. The machine has been tested for planting on complete and single furrow ploughing, and also for direct planting of unploughed ground. First results are encouraging, as the machine has proved more versatile than expected regarding the topography and type of ground on which it can work. The machine has planted at rates from 8,000 to 12,000 plants per day in a variety of conditions; assessments of plant survival will be made shortly. Work is now proceeding to modify the machine to permit wide shallow ploughing and planting in one operation.

Afforestation Problems on Limiting Sites 233

A third season's work has been completed at Croft Pascoe on the exposed Lizard Peninsula of Cornwall. This site is of special interest as it is located on Serpentine rock, a formation on which there has been little afforestation experience. The experiments laid down from 1954 to 1956 include extensive trials of species, with investigations of ploughing methods, position of planting on plough ridges, manuring (nitrogen, phosphorus, potassium and calcium), use of nurse crops of pine and broom; and methods of direct sowing including techniques for protection of seed against vermin.

The main impression at the end of the second growing season in 1955 was of normal growth of a considerable range of species. In particular, Sitka spruce. *Pinus contorta* (coastal provenance), *Pinus radiata*, and *Pinus pinaster* show good early growth. Many more species were added in 1955 and and all have survived well with the exception of Corsican pine and *Cupressus macrocarpa* which showed forty to seventy per cent deaths. Broom (*Sarothamnus scoparius*) has grown vigorously to five feet in two years and would seem to be of value as a shelter species to aid afforestation on such exposed ground. There is a very large response by many species to manuring with phosphate and potash compound fertilizer, and an experiment has recently been laid down to separate the effects of phosphate and potash. Latest experiments also examine date of planting, and the inclusion of *Thuja plicata* and *Cupressocyparis leylandii* among other species.

Wareham and Purbeck Heaths

Comparative trials of ploughing methods and of species were carried out at these forests, with the object of providing information on the performance of a range of species on impoverished soil in the Wareham area, using modern methods of ploughing and manuring. There have been many species comparisons at Wareham, but until now there was no direct comparison of the best indicated species with modern methods of ground preparation. The latest trials include species comparisons on Tine and R.L.R. ploughing on new ground at Purbeck, and species trials at Wareham on a site cleared of checked Scots pine in 1955. A survival trial with four species has also been planted at Hyde Bog, Wareham, with a view to providing guidance for more extensive planting in the near future.

Coed Taliesin

Certain mineral soil types over shale on steep land in mid-Wales have caused difficulty in crop establishment, and resulted in crops of slow and unsatisfactory growth in a dense vegetation mat of grasses and *Ulex gallii*, *Vaccinium* and *Calluna*. Extensive areas of similar land have been acquired in this district and are characterised by compacted mineral soils on variable, but often steep slopes. Seasonal drought, surface soil compaction and intense vegetation competition are among the main factors limiting growth. In view of the absence of experimental establishment work on mineral soils at these elevations, an extensive set of experiments was laid down at Coed Taliesin, Cardiganshire, in 1956. Particular attention has been paid to ground preparation, including trials of deep and shallow single furrow ploughing, deep complete ploughing and deep ripping of the site combined with, or preceding ploughing. In addition extensive trials of species on both ploughed and turfed land have been planted, together with a factorial test of phosphate and potash fertilisers.

Pennine Forests

In the Pennines in northern England, in addition to the difficulties of exposure on high land and difficult soil conditions, there is the added problem of air pollution. In pilot plots established five years ago many conifers, especially Sitka spruce, have not made the expected growth, and it is considered possible that on the marginal conditions obtaining, the pollution of the air may be a cause of the repeated defoliation and death of leading shoots which occurs. Hardwoods have also proved difficult or impossible to establish on these plots, in spite of experimental application of lime, nitrogen and mulches.

A further set of plots is planned on another site, and at the same time the assessment of sulphur dioxide in the air by the standard lead peroxide method, as carried out in urban areas, is to be extended to various sites where trees are growing both healthily and with difficulty, to try and find out the levels of pollution to which they are subjected. A number of Water Catchment authorities are co-operating in this scheme.

Trials in the North of Scotland

In the far north, as noted last year, more information on the performance of the trees in the pilot plots laid down in exposed localities in Caithness, Sutherland, Orkney and Shetland will be necessary before further advances in afforesting such sites can safely be made. The summer drought did not appear to have any serious detrimental effects, but the spring cold caused the usual die-back and loss of needles. The results of several of the experiments which started well, and which by now should be getting established, are so far disappointing.

Establishment of Hardwoods in Scotland

In continuation of this project, comparative plots of *Nothofagus procera* and *N. obliqua*, on ploughed and unploughed ground, were planted, and also a beech provenance experiment. Plots of oak (pedunculate and sessile) and sycamore were also established.

Comparison of Pure and Mixed Crops

The series of mixture experiments described in the 1955 *Report*, has been enlarged by the addition of two experiments with Scots pine and Western hemlock at Speymouth forest, Morayshire; and Devilla forest, Fife.

Fixation of Sand Dunes

At Newborough Warren, Anglesey, where dune fixation by thatching and marram-planting is in progress, a trial of bituminous emulsions for temporary sand fixation after direct sowing or planting was carried out in 1955. Both labile and stable cold bitumen emulsions, sprayed at rates down to ten square yards per gallon, resulted in fixation of the surface sand for a full season following application. Plots receiving lighter applications, i.e. down to twenty-five square yards per gallon, were 'blown out' during a gale in May, 1955, about six weeks after treatment.

All the sprayed plots were direct sown or planted with Corsican pine and *Pinus radiata* immediately before spraying. Planted trees of both species showed very poor survival, but direct sowings developed vigorously, the seedlings breaking through the bitumen crust without apparent difficulty. These seedlings grew satisfactorily throughout the hot dry summer of 1955, but became browned and blasted in the autumn. Seedlings from seed sown in thatched 'control' plots appeared quite healthy, as did the few seedlings on the edge of bitumen plots immediately in the lee of thatched plots. It appears that the failure of seedlings after a most promising start on the bitumen plots must be attributed to the complete absence of any shelter against the prevailing winds, salt spray and sand blowing over the surface of the bitumen. The experiment was an extreme test of the technique, as the plots were situated in an exposed position within 100 yards of high tide mark, and the method warrants further trial under less severe conditions.

Improvement of Checked Plantations 236.2

Investigation of methods of improvement of unsatisfactory slow growing or 'checked' crops has continued at several forests, with the objects of determining the most satisfactory methods of crop replacement or stimulation of growth of the existing crop. At Wilsey Down in Cornwall, where Sitka spruce is badly checked on ploughed ground, further manuring experiments were laid down, and experiments started in 1953-54 are beginning to show results. Broadcast application of phosphate and potash compound fertilizer to checked trees in dense ground vegetation resulted in a marked growth improvement in 1955. The response was considerably greater than expected, and this result has been followed up by more extensive manuring experiments to examine the separate effects of phosphate and potash, at a range of rates. Tests of broom as a nurse crop have been planted, but after three seasons there is little measurable effect on the tree crop. Extensive plantings of coastal *Pinus contorta* as a nurse crop are growing well and may assist in suppression of the difficult vegetation on this site in due course. A species trial has been planted in a matrix of *P. contorta* to test species development on one of the worst checked areas.

In collaboration with Dr. Leyton of the Imperial Forestry Institute, Oxford, small-scale trials of paper mulching, manuring and chemical control of vegetation, were established in 1955 at Ringwood Forests, Hants, on an area of checked Sitka spruce in dense *Calluna*. Manuring tests included trace element applications and comparison of nitrogen applied in a foliage spray and as a basal application. Iso-butyl, 2, 4-D in kerosene was applied to kill the *Calluna* on an experimental scale. First results should become apparent during 1956. New experiments are in hand on checked pine at Wareham, Dorset, and on checked spruce at Tarenig in mid-Wales. These trials will include more extensive tests of chemical and mechanical eradication of competing vegetation, and of manuring treatments to revive the existing crop.

Manuring in the Forest 237.4

A number of experiments on manuring of trees shortly after planting have been mentioned under the work on afforestation of particular types of land. In addition, a very extensive set of forest manuring experiments laid down by Conservancy staff in 1951 at over 200 sites throughout the country was inspected and assessed by Mr. R. G. Green, on temporary service with the Research Branch from the Commonwealth Forestry Bureau, Canberra, Australia, and form the subject of an article in Part III of this *Report*, page 132.

In the North, more trials of triple superphosphate as a possible alternative to ground mineral phosphate were laid down. In spite of the drought, which might have been expected to accentuate losses, there were no disasters. In a comparison of superphosphate and ground mineral phosphate started three years ago, there have been indications of a better result from the mineral phosphate on deep peat, but on heathland no difference was observed. The effect of varying rates of lime applications in the same experiments has been negligible so far in all cases.

Natural Regeneration 234

Collection of information on this subject continues, and a list of occurrences of natural regeneration in private and State woodlands is being compiled with detailed reports on those that appear most promising. These occurrences have mostly arisen spontaneously, and on account of the time that usually elapses between the occurrence of the factors responsible for the regeneration and the discovery of the seedlings, it is difficult to obtain a proper understanding of the conditions controlling their appearance. Species reported on include Scots and lodgepole pines, European larch, Norway spruce, *Tsuga* and beech.

Observations have been continued on earlier experiments with regeneration of native Scots pine. In general these experiments have not been successful, probably because the development of unsuitable ground vegetation conditions through selective cutting, grazing and neglect of drainage, had gone too far before attempts at regeneration were started.

During the year one such site has been taken over by Research Branch as an experimental and observational reserve. This is an area of 240 acres comprising the western end of the Black Wood of Rannoch, Perthshire. While the more direct method of group clearing, draining and replanting with local pine is applied to the bulk of the Black Wood, the Reserve will be maintained for observation of the changes in site conditions and regeneration which occur under a minimum of treatment, using as a basis an ecological report made in 1949. Experimental work will be confined to small-scale experiments on the factors controlling natural regeneration.

PROVENANCE STUDIES

By R. LINES

Lodgepole pine 232.12

IN FURTHERANCE of the study of lodgepole pine, *Pinus contorta*, which has been carried out during the last two years, a visit was made to Ireland to study the older stands of the coastal provenances which are poorly represented in Britain, and at the same time to make more detailed notes of the stands from which the Forest Service of the Irish Republic kindly sent us seed in 1954. During this visit stands in both Northern Ireland and the Irish Republic were examined. In brief it can be said that most of the successful older stands originate from seed from the Coast of Washington or Oregon and that there is a considerable variation in growth form. The general picture is that this south coastal type of lodgepole pine is an extremely vigorous and tough tree capable of making rapid growth under conditions of poor soil or great exposure. It is not a handsome tree, however, and the form is often very rough and branchy, so that its chief use would appear to be as a pioneer crop. There have been severe attacks of the pine sawfly (*Diprion pini* L.) on lodgepole pine in both Northern Ireland and the Irish Republic. It was noticeable how the inland forms of lodgepole pine were much worse attacked than coastal type crops.

Seed from the Irish stands was sown in 1955, together with a set of collections from British stands and two direct from American forests, in all fifteen different provenances. At the end of the first year in the nursery there were highly significant height differences, but perhaps the most striking results were that, without exception, all the provenances which originally came from the south coastal range of lodgepole pine were above the average height of the whole experiment, while the inland provenances were below it. The north coastal provenance, originally from the Queen Charlotte Islands in British Columbia, was also below average. The third tallest lot, from Kilworth forest, County Cork, is perhaps an intermediate type. The parent stand, which was seen during the tour, is of a type markedly different from normal south coastal lodgepole pine, The other result was that when the experiment was inspected in October there were very considerable colour differences in the plants. In general, the south coastal origins were a grassy-green while those from higher latitudes were purple-green or blue-green. Later on, the colour differences became less apparent, and it is postulated that the differences are caused by the earlier cessation of growth and hardening of the tissues of the northern provenances, compared with those from lower latitudes.

European larch

As noted in the *Report on Forest Research for March*, 1952, experiments were planted in 1951-52 at Thornthwaite, Cumberland and Drumtochty, Kincardineshire, to test the performance of various provenances of European larch on sites where "die-back" had occurred. A similar experiment was planted at Glen Isla, Angus, in 1952, on a moorland site.

Height and failure assessments after three years' growth in the forest show some highly significant results. At Drumtochty the best height growth of European larch has been made by a provenance from Mala Wies in Poland, followed by those from Moravia (genuine Sudeten larch) and Schlitz, Hesse. Scottish provenances and Münsterthal are equally poor. It is known that Münsterthal larch is susceptible to "die-back" in Britain. The best growth of all has been made by Hybrid larch, but the Polish larch provenance has grown faster than Japanese larch here. At Thornthwaite, Polish larch again shows its superiority over all other provenances, but here at the present time the Münsterthal provenance is making better growth than the Scottish provenances from Altyre (Moray), Strathconon (Ross), Farigaig (Inverness) and Millbuie (Moray). Sudeten larch is intermediate for height growth between the Polish and Scottish lots, and it is closely followed by the Schlitz origin.

At Glen Isla forest the same provenances are represented, and again the same pattern of growth occurs, except that the differences are not so pronounced. The Mala Wies provenance is tallest, followed in decreasing order by Sudeten, Schlitz and the best Scottish provenance, Millbuie. Here, however, the Münsterthal provenance has made the least height growth.

There were heavy failures on establishment at both Thornthwaite and Drumtochty, and these may be attributed chiefly to drought conditions after planting. However, there were significant differences in the survival percentages, more deaths occurring in the Münsterthal provenance than in any other at two of the experiments. The Polish larch and Sudeten larch showed relatively few failures.

These experiments will again be assessed when "die-back" symptoms become apparent in any of the provenances. Slight shoot die-back, probably by frosting of the early flushing Münsterthal provenance, has already been reported from Thornthwaite. "Die-back" usually becomes apparent only in the thicket stage, and it is not expected that any conclusive result will be obtained before this stage is reached.

A replicated experiment with four provenances of European larch was planted at Durris Forest, Kincardineshire, in 1940. Similar experiments using the same provenances were planted in Wales at Mynydd Ddu, Crychan and Brecon, all in Brecknockshire. The experiment at Durris is laid out as a four-by-four Latin square, and the plot size is one acre, so that long-term volume records should be possible. The provenances are Darnaway Estate, Morayshire; Sudeten, Bohemia; Inn Valley, Austria; and Trentino, Italian Alps. Establishment was obtained with only slight losses, and there was nothing to choose between provenances on this account. In 1947 it was recorded that no "die-back" had yet occurred, and that there were a number of obvious hybrid larch in the Sudeten plots. By 1949, however, trees in one plot of the Inn Valley provenance had begun to die, due to frost and subsequent canker, but it was not at all general. In 1951 a height assessment showed that the Darnaway provenance was tallest, with Sudeten and Trentino not very far behind. The Inn Valley provenance was significantly smaller. In this and subsequent assessments the hybrid trees noted above were not included. By 1951 the thicket stage had been reached in the better grown plots, but in those on the poorer soil and in greater exposure at the top of the experiment failures had increased, and there were large gaps in many of the Alpine plots. Die-back had reached serious proportions in the Inn Valley and Trentino provenances, but some trees were also killed in the Darnaway and Sudeten plots.

By 1954 dead and missing trees amounted to some twenty-five per cent in the worst plots of the Trentino and Inn Valley provenances, whereas they were only about sixteen per cent in the worst Darnaway and Sudeten lots. The Darnaway plots showed the best resistance to "die-back" and had a mean survival of ninety per cent. The experiment was assessed for height and girth at the same time. There were significant height differences, and these followed the same pattern as the 1951 assessment. The most striking feature, however, was the very small increase in mean height over a period of three growing seasons. One can only attribute this to the prevalence of "die-back" to the leading shoots, which is borne out by the fact that the greatest increase in height growth has been made by the Darnaway provenance which shows least "die-back". The girth records do not show significant differences between provenances. It is interesting to observe that the mean height of the hybrid trees in the Sudeten plots is nearly twice the mean height of the true Sudeten trees. These hybrids were beginning to interfere with the other trees in the plot, so they have been removed from two columns of the Latin square.

Douglas fir

In the *Report on Forest Research*, 1954, it was recorded that trials of seed sources from Washington and Oregon had been planted at Laiken (Nairn) and Glentress (Peebles) in 1953. The following year the same set of provenances was set out at Sunart (Argyll) to include a site with the typical high rainfall and mild winter of the West of Scotland.

The experiment at Glentress had been planted adjacent to a similar trial planted in 1952 to compare typical Coastal Oregon Douglas fir with a provenance, var. *caesia*, from Shuswap Lake in the interior of British Columbia.

Both experiments had been successfully established with only slight losses and in the 1952 experiment the third year height assessment showed that the Oregon provenance had made appreciably better growth than the Shuswap Lake origin. During the winter of 1954-55, and long before any plants had flushed, it was noticed that a large number had been frosted back and some plants were dead. This winter cold injury is not common on Douglas fir in Britain, but has been responsible for various failures in Continental Europe.

An assessment of the die-back carried out in the Spring of 1955 showed that there were only slight differences between any of the Washington or Oregon provenances, which are all of the var. *viridis* type, but few of the var. *caesia* type were seriously frosted back. Some of these var. *caesia* plants had been included with the main experiment in the 1953 planting, so that they were equally exposed to the cold winds which it is thought caused the damage. It will be interesting to see whether this type of injury is recurrent on this site, and to observe whether it enables the more frost resistant var. *caesia* to make faster height growth than the coastal type here.

REHABILITATION OF DERELICT WOODLANDS

By A. D. MILLER

25

WORK HAS CONTINUED on a number of different aspects of rehabilitation; three new sites have been added to the series of costed experiments dealing with the main soil and cover types which now needs only one more site for completion; while the trials of heavy machinery for scrub clearance have proceeded.

Rhododendrons

The fourth and last of the costed experiments on the eradication of rhododendrons was laid out on Bagshot sands at Hurn Forest in Hampshire. The treatments were all designed to give eventually a fully stocked conifer crop of a species which would cast a sufficiently dense shade to suppress any uncut rhododendron, and were also designed to compare both the initial economy and any later effects on revenue which may result from partial cutting and planting in strips.

The treatments were:

(*a*) Clear cut and plant with *Tsuga heterophylla* at 5 feet by 5 feet or 1,742 trees per acre.

(*b*) Cut strips 10 feet wide leaving 10 feet of uncut rhododendron between adjacent strips, planting two rows of *Tsuga heterophylla* at 4 feet by 5 feet in each cut strip, giving 871 trees per acre.

(*c*) Cut strips 5 feet wide leaving 10 feet of uncut rhododendron between adjacent strips, planting one row of large *Tsuga heterophylla* plants, 3 feet high, spaced at 8 feet apart down the centre of each cut strip, giving 363 trees per acre.

Eight replications were made, using half-acre plots in random block design, and the following mean initial costs were recorded. See Table 9.

Rhododendron Suppression Experiments, Hurn, 1955:
Mean Costs per acre of Preparing Ground and Planting

Table 9

Operation	(*a*) Clear Cut	(*b*) 10 ft. strips 10 ft. uncut	(c) 5 ft. strips 10 ft. uncut
	£ s. d.	£ s. d.	£ s. d.
1. Preparation of Ground	46 11 4	25 12 10	13 15 0
2. Plants	16 2 0	8 1 0	7 5 0
3. Labour cost of planting....	5 11 0	2 15 6	2 0 6
4. Total	68 4 4	36 9 4	23 0 6

Labour is charged at 2/10d. per hour, the normal plants used in treatments (*a*) and (*b*) at 185/- per thousand, and the large plants in treatment (*c*) at 400/- per thousand.

Some general comments on the use of strip planting amongst rhododendron were made in last year's annual report, so that it is now necessary only to emphasise their attractive initial economies; however, the question of which treatment will be the most profitable over the whole rotation cannot yet be settled.

Hazel Coppice

An experiment established in 1951 at Gardiner Forest, Wiltshire, to compare different ways of manipulating old hazel coppice to convert it to a pure beech forest has been mentioned in the reports of previous years, but for some time it has been felt that it would be desirable to add a number of new treatments, including the use of conifers to improve the cash returns from early and intermediate thinnings. Therefore, a new experiment was laid down at Stonedown Wood, Gardiner Forest, using six replications of half-acre plots in random block design, to compare the costs incurred and the type of crop produced by the following treatments:

(*a*) Clear cut and burn the old coppice and plant Douglas fir at 6 feet by 6 feet, or 1,200 trees per acre.

(*b*) Clear cut and burn, planting two rows of beech/three rows European larch, all at 5 ft. by 5 ft., or 1,742 trees per acre.

(*c*) Clear cut and burn, planting alternate rows of big transplants about 3 ft. high, of beech and Lawson cypress, spaced at 8 ft. x 8 ft., or 682 trees per acre.

(*d*) Thin the hazel coppice lightly and uniformly, underplanting throughout with Douglas fir at 6 ft. x 6 ft., giving 1,200 trees per acre. The cut coppice stems were laid in rows 12 ft. apart so as not to interfere with the spacing of Douglas fir; no burning was done.

(*e*) Cut strips 8 ft. wide leaving 8 ft. of untouched coppice between adjacent strips, thus clearing 50 per cent of the cover; the cut stems were laid or pushed into the uncut hedges between the strips and no burning was done. One row of large transplants about 3 ft. high, alternatively beech and *Thuja plicata*, spaced 8 ft. apart, was planted along the centre of each cut strip, giving 341 plants per acre.

(*f*) Cut gaps in the coppice 8 ft. in diameter and 16 ft. centre to centre, planting a single large *Thuja plicata* about 3-4 ft. high in the middle of each gap. When forming these gaps a deviation was allowed of up to 3 ft. from the theoretical position in any direction, in order to take advantage of natural openings in the canopy. This gives 170 trees per acre and involves cutting just less than 20 per cent of the cover.

(*g*) Plant *Tsuga heterophylla* at approximately 6 ft. x 6 ft. directly underneath the untouched coppice without doing any preparation of the ground at all, though a certain amount of local tidying was done with spades at the time of planting; 1,100 trees per acre were planted.

The costs are recorded in Table 10.

Gardiner Forest Experiments, 1955:
Mean Costs per acre of Preparing Ground and Planting

Table 10

Operation	(*a*) Clear cut Douglas fir 6 ft. x 6 ft.	(*b*) Clear cut Beech/ European Larch 5 ft. x 5 ft.	(*c*) Clear cut Beech/ Lawsons Cypress 8 ft. x 8 ft.	(*d*) Thin and Underplant Douglas fir 6 ft. x 6 ft.	(*e*) Strips Beech/ Thuja 8 ft. x 16 ft.	(*f*) Gaps Thuja 16 ft.x16 ft.	(*g*) No preparation Tsuga 6 ft. x 6 ft.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1. Prep. ground	38 14 0	38 14 0	38 14 0	22 16 0	20 14 0	8 14 0	— — —
2. Plants	9 0 0	13 8 9	13 12 9	9 0 0	6 16 5	3 8 0	9 18 0
3. Labour cost of planting	3 0 0	4 2 6	16 0 0	3 0 0	8 0 0	4 0 0	4 10 0
Total	50 14 0	56 5 3	68 6 9	34 16 0	35 10 5	16 2 0	14 8 0

It is expected that the use of large transplants and the maintenance of shade in some treatments during the early years will reduce the weeding costs very considerably compared with those plots which were clear cut and planted with normal sized trees. However, it remains to be seen by how much the total costs of establishment are reduced by these slightly unusual methods.

Poor Quality Forest

An experiment was laid down at Flaxley in the Forest of Dean to compare a number of economic and silvicultural results of different methods of treating a poor quality semi-natural high forest. The woodland consisted of both maiden and coppice stems of birch, lime, alder, wych elm, willow, sweet chestnut, ash, sycamore, and oak, with a top height of roughly forty feet. The soil is derived from the Old Red Sandstone and is very fertile. A number of well-shaped and promising trees were scattered through the forest, but the general quality of the growth was low and there was no prospect that a fully stocked or valuable final crop could be developed by tending the existing stand. However, a large number of the stems were saleable for cordwood or turnery, so that the financial advantages of methods involving partial cutting were questionable, and it remains to be seen whether, under these circumstances, the silvicultural advantages gained by leaving shelter for the new crop will compensate for the reduction of early revenue.

Five replications of the following treatments were made, using half-acre plots in random block design:

(*a*) Clear cut the existing stand and replant with a 3 row—3 row mixture of oak/European larch to be managed so as to use the larch for early and intermediate thinnings, aiming at a final crop of pure, or nearly pure oak.

(*b*) Clear cut and replant with pure Douglas fir.

(*c*) Thin the existing stand evenly, where possible leaving well-shaped young trees of valuable species, and underplant throughout with alternate lines of *Nothofagus* sps./*Tsuga heterophylla*.

(*d*) Thin as in (*c*) and underplant with pure *Tsuga heterophylla*.

(*e*) Make the best of the existing crop, but planting *Nothofagus* or Douglas fir to produce full stocking.

(*f*) Untouched; partly to act as a demonstration of what was on the ground before operations started, and partly to follow the natural development of this type of woodland.

Details of all produce prepared were kept, and in treatments (*c*), (*d*) and (*e*), all the uncut stems were measured; records were also kept of the work involved in extracting produce to roadside.

An additional study was superimposed on this layout by dividing each clear-cut plot into two equal parts and applying sodium arsenite to all freshly cut stumps in one half only. In future operations these half plots will be costed separately and the effects on total costs of establishment will be recorded.

At the time of writing not all the collected data have been worked up, but the available figures appear in Table 11:

Table 11 *Flaxley Experiments, Dean Forest,* 1955: *Mean Initial Costs per acre*

	Treatments (*a*) and (*b*) Clear cut	Treatments (*c*) and (*d*) Thinning	Treatment (*e*) Retain groups
	£ s. d.	£ s. d.	£ s. d.
1. Preparation of ground and preparation of produce (paid at day rates)	58 11 4	42 17 4	50 16 0
2. Value of produce	59 0 0	38 0 0	50 0 0

Mechanical Scrub Clearance

The experiments at Bernwood and Pytchley forests, mentioned in the 1955 *Report*, have been continued, work has been done on two other areas, and several new sites have been chosen.

The Bernwood (Oxford) and Pytchley (Northants) sites together form a single experiment in which the costs, efficiency, and certain effects on the site of using a number of mechanical methods of scrub clearance are compared. Six replications of six treatments using five-acre plots were used, giving a total area of 180 acres. The costs of the initial cutting or grubbing up were separated from the costs of burning or windrowing the debris, and alternative methods of disposing of the woody material were compared. The first stages of clearance have been completed by the following methods, all using tracked tractors:

(*a*) "Fleco" tree cutter, a horizontal cutting blade fixed to a tractor and using its momentum to chisel through stems at ground level; root systems remain and the soil is little disturbed. Being relatively free from roots and soil the debris burns fairly easily.

(*b*) Grubber blade, a toothed digging blade designed to remove root systems and to do some cultivation. Unavoidably a good deal of soil becomes mixed with the debris and complete burning is sometimes difficult.

(*c*) "Sabre" cutter, a circular saw mounted on a hydraulically controlled boom in front of a tractor. Stems are cut at ground level and the soil is not disturbed so that burning is fairly straightforward.

(*d*) Anchor chain between two tractors. The tractors are driven through the scrub on parallel courses about twenty feet apart (if the scrub is very dense rackways, cut previously, may be used) and about 150 feet of chain is allowed to form a loop behind them. As the tractors are driven forward the chain should break or uproot all woody growth over which it is dragged. In practice, the chain had to be heavily weighted to prevent it riding over low scrub, and the texture of the soil, by determining the firmness with which the roots are held in the ground, had important effects on the results of this method. Early results are promising and variations to improve the efficiency of this technique are being tested.

At an early stage in these trials it became apparent that the burning or other disposal of the woody debris was equally or more expensive than the cutting or grubbing which preceded it, and various ideas have been tested to try to reduce these costs. This work continues, and it is not yet possible to quote comparable costs for clearing and burning, but it is quite evident that the man-power requirements to prepare scrub woodlands for planting can be greatly reduced by the use of heavy machinery, while the total cost including overheads can be reduced to between one-half and one-quarter of that incurred in hand cutting and burning.

CHEMICAL WEED CONTROL, BARK PEELING AND ANIMAL REPELLENTS

By G. D. HOLMES

Control of Woody Species 243.8:441

DURING THE YEAR experiments testing growth-regulating compounds for controlling shrub and tree weed species were extended to include additional species and compounds. *Rhododendron ponticum* has proved one of the most difficult species to control, and new experiments were started at Beddgelert and Bramshill Forests to cover cut stump and basal bark treatment of standing growth, with 2,4,5-T and the untested compounds 3-amino triazol and 2,3,6-trichlorobenzoic acid. These experiments are not yet complete, but first results confirm the effectiveness of ammonium sulphamate at 4 lb. per gallon of water as a cut stump treatment. 2,4,5-T ester at 0.1-0.2 lb. (acid) per gallon of diesel oil also shows promise as a stump treatment. Summer foliage spraying of regrowth has proved ineffective for prevention of further regrowth. Previous experiments on oak and birch coppice and maiden growth indicate that cut stump or basal bark spraying with 2,4,5-T and/or 2,4-D holds considerable promise for controlling these species. Ethyl butyl 2,4,5-T at 0.1 lb. (acid) per gallon of oil was successfully used as a basal bark spray on birch at Bedgebury in 1955 to carry out a "chemical thinning" in an overdense crop. This treatment was also used successfully at St. Clements Forest, Cornwall, to kill and thin the canopy of large oak coppice which had previously been underplanted with *Eucalyptus* species. A series of experiments was established in 1955 to test the effectiveness of a wide range of treatments for controlling standing growth, regrowth and cut stumps of ash, birch, chestnut, hazel and alder. These trials include examination of treatment dates, dosage response, and position of application for several compounds including 2,4-D, 2,4,5-T, 3-amino triazol, and 2,3,6-trichlorobenzoic acid.

Continuation of trials on *Calluna vulgaris* has yielded encouraging results. In 1954 satisfactory control was obtained by summer spraying with iso-butyl, 2,4-D at 5 lb. (acid) in 160 gallons of oil per acre. Detailed experiments in 1955 on rates and volumes of application in oil and water show that good control is possible using oil or water as the diluent at volumes down to 25 gallons per acre. 2,4-D at rates less than 5 lb. (acid) per acre resulted in incomplete control, unless combined with high volumes of oil diluent. Thus 2.5 lb. 2,4-D in 120 gallons of oil per acre gave similar good control to 5 lb. 2,4-D in 25 gallons of water per acre. Large-scale trials of the lower volume spray treatments are to be carried out in 1956. 2,3,6-trichlorobenzoic acid appears effective as a foliage treatment on *Calluna* at rates of 5-10 lb. (acid) per acre. 2,4,5-T has proved much less effective than 2,4-D at rates up to 5 lb. (acid) per acre.

Control of Vegetation on Fire Traces and along Fence Lines 432.1

Experiments have been established at three forests, viz. Bruton and Blandford (heavy soils) and Bramshill Forest (sandy soil), to test a wide variety of treatments for long-term control of vegetation on cultivated and uncultivated fire traces. Compounds under test include CMU, DCMU, 'Borascu', borax and sodium chlorate compounds, sodium TCA, sodium arsenite, and 'Dalapon' and 2,4-D. A study is being made of the initial toxicity and persistence of a range of rates of these compounds.

Chemical Bark Peeling 243.8:361.9

An account of some preliminary experiments on the use of chemicals to assist bark removal of pole stage conifers was given in the *Report on Forest Research*, 1955. In 1955, a large-scale costing trial was carried out on Scots pine, Sitka spruce and Japanese larch, at three forests, to examine the economics of the technique. Sodium arsenite (40 per cent AS_2O_3) applied to band girdles on selected trees in late spring, was used as the best indicated treatment, and detailed records were kept of subsequent felling, snedding, peeling, extraction, and loading costs. These trials are still in progress, but first results are disappointing. Peeling costs in the autumn following treatment were not reduced, owing mainly to tightening of the bark at the top of treated trees. Wood weight was reduced by 40-50 per cent as a result of treatment, but to date this has not been reflected by a marked reduction in extraction and handling costs. These costing trials will be completed by early summer 1956. The use of sodium arsenite to facilitate bark peeling of hardwoods was the subject of trials in the Forest of Dean in 1954. Application of a 40 per cent AS_2O_3 solution to band girdles was tested at a range of dates on mature oak, and pole stage trees of oak, ash, beech, chestnut, elm, and sycamore. Examination of bark looseness, at intervals throughout the season following treatment, showed considerable variations in the reaction of the species.

Both oak and chestnut peeled easily in the autumn and throughout the season following treatment. Ash and sycamore, however, peeled badly, having tight strips of bark at many points on the stems. Birch, elm and beech were intermediate in that peeling was easy over the lower two-thirds or so of stem, but bark remained completely tight, or tight in strips, at the top of the stems.

Unlike most conifer species treated, none of the hardwoods showed any appreciable loss of wood weight through moisture loss following treatment. It was hoped that the technique may have some value for assisting peeling of oak for tan bark production, but this now seems unlikely as analyses by the British Leather Manufacturers' Research Association indicate that the tannin content of bark from treated trees is depressed by the poison to an uneconomic level, this effect is apparent in the winter following treatment.

Chemical Repellents for Protection of Seeds and Trees against Animals

Protection of Direct Sown Seeds 451.414

Extensive losses of direct sown seeds of *Pinus radiata* and *Pinus pinaster* in experiments at several centres has stimulated interest in the possibilities of seed pretreatment to prevent this damage. At Croft Pascoe Forest in 1955 it was found that application of a bitumen spray to direct sown patches offered little obstacle to attacks by wood mice (*Apodemus sylvaticus*). However, covering the seed with coarse grit followed by a bitumen spray gave a high measure of protection. A number of chemical repellents are now being tested as seed dressings, including tetramine and W.R.L.-2 developed and supplied by the United States Wildlife Research Laboratory. Other compounds under test include cyclohexamide, tri-nitrobenzene aniline and a number of proprietary compounds.

Protection of Planted Trees.

As reported in the *Report on Forest Research*, 1955, page 40, bone oil or resin have proved effective repellents for the protection of the basal bark of poplars against rabbits. These compounds, along with others, are now being tried for protecting newly planted poplars against deer damage. Work is also being done on the pretreatment of conifer stocks prior to planting in the forest.

FOREST ECOLOGY

By J. M. B. BROWN

Water Relations of Clay Soils 114.12

REFERENCE WAS made in the 1955 *Report* to preliminary measurements of the levels of standing water in drained and undrained Oxford Clay in Waterperry Wood (Bernwood Forest). These measurements were continued fortnightly through 1955, a year distinguished by rainfall deficiency and marked excess of warmth and sunshine from mid-June until early October. The April drought was also noteworthy. Small differences in water levels between the three drainage treatments were maintained until the end of June, but in July water disappeared from all the test holes, which did not become recharged until November. At the end of the year the levels were still considerably below those of December, 1954.

From June until the end of the year, fortnightly gravimetric estimates of soil moisture were made in quintuplicate at a depth of five to fifteen centimetres in each treatment. The two June assessments showed a significantly lower soil moisture content in the intensively drained plots, than in those with normal draining or no draining. During July, however, the surface soil became equally dry in all three treatments, and from mid-July until the October rains, moisture contents were similar throughout, about, or somewhat below, the estimated wilting coefficient of the clay soil.

It is clear from these observations, which are being continued, that for a long period during the summer of 1955, moisture in the surface soil fell far below the optimum for plant growth. It is likely that this happens each summer, though perhaps only for short periods. At deeper levels the relatively impermeable clay retains moisture much longer, but plant roots probably make little use of this moisture. The drainage treatments are intended to reduce winter wetness so as to improve the depth of root penetration and render the trees less dependent in summer on the fluctuating moisture content of the surface soil. The observations made at Bernwood have shown that drainage has some beneficial influence on winter wetness of the soil, but the effect on the exploitation of the soil by tree roots remains to be assessed when the trees are older.

Ecology of Corsican Pine in Britain 181

The survey of Corsican pine growth was extended to Scotland, where, although extensive stands of this tree are rare, there are numerous small woods and groups of trees, representing an interesting range of ecological conditions. The collection of information about Corsican pine in the north of Britain is by no means complete, but the evidence indicates that there is only limited scope for using this tree in the north, and that local factors of soil and topography may decisively affect performance outside its normal climatic range.

In the south a number of stands at relatively high altitudes (1,000-1,250 feet) were observed in an advanced stage of disease at an age of twenty-five to thirty years. What appears to be a complex ecological problem is presented by these stands, which develop satisfactorily for about twenty years and then, over a period of several years, fall victims to severe defoliation associated (at least in most cases) with the fungus *Brunchorstia destruens*.

Corsican pine has often been planted on coastal sand dunes, where again early promise is not always fulfilled. Dune plantations have been examined at Culbin (Moray), Tentsmuir (Fife), Holkham (Norfolk), Pembrey (Carmarthen) and Formby (Lancashire). A distinction must be made between east coast dunes and west coast dunes, where the effects of wind are important over a wide area.

It need not, however, be doubted that the difference is one of degree: planted on the coastal dune Corsican pine suffers from blast all round the coast, but on fully exposed west coasts the affected zone is much wider than on the east.

While climatic factors have received most attention, some consideration is being given to soil factors, in view of evidence that these may exercise a decisive influence on marginal sites. In the south, where the tree appears climatically suited, attention is being directed to the soil conditions of Quality I stands and to the performance of Corsican pine on the outcrop of Cretaceous Chalk.

Natural Regeneration of Beech 231

Observations were continued in Watlington Forest (Queen Wood), where, in areas not dominated by *Rubus fruticosus* or *Deschampsia caespitosa*, the 1950 mast yielded a locally abundant crop of seedlings. The weather of 1955 provided a complete contrast to the weather of 1954, in which seedlings in trenched quadrats showed better survival than seedlings in untrenched quadrats, but no advantage in height increment. In the sunny, warm and rather dry summer of 1955 it was expected that shade might prove less, and root competition more, influential than in 1954. In the assessment carried out in November, 1955, the trenched seedlings showed no better survival, but superior height increment, as compared with control seedlings. Deaths were fewest in the four quadrats receiving twenty per cent of daylight or over, whereas most of the quadrats receiving five per cent light, or less, showed high mortality rates. Height increment in 1955 was also above the average in the well-lighted quadrats, but there were many anomalies and no clear correlation could be traced between relative light intensity and growth of the seedlings. Attention should, however, be drawn to the fact that height increment has been used as the sole measure of growth in this experiment: it is known from previous observations under artificial shade that dry weight increment is a much more sensitive indicator of the effect of shade on beech seedlings.

The effect of exposure to the west wind is important for the Watlington regeneration and this has embarrassed the attempt to elucidate the relative effects of shade and root competition. It is evident that, under these conditions, two replications of the three degrees of opening of the canopy, provided in February 1952, are inadequate. After the 1956 assessment it is intended to report in detail on this experiment and the ancillary observations made over the past four years, during which the fate of more than 1,000 beech seedlings has been followed. The promised beech mast of 1956 may provide opportunities for more fully replicated studies, in Watlington Forest or elsewhere, of the significant factors.

Experiments connected with the natural regeneration of beech are also in progress in Slindon Park, Sussex (National Trust), where in 1955 protection by mouse and bird proof netting resulted in a significant increase in the number of beech seedlings in September. Within the netting there was also a significant positive result from the application of ground chalk to the surface in March, 1954. The effect of the chalk on subsequent growth of the seedlings in this acid soil is under investigation.

SOILS

By Dr. W. H. HINSON

114

THIS IS THE FIRST REPORT from the recently established soils section at the Forestry Commission Research Station, Alice Holt. Efforts have largely been directed to the provision of facilities for chemical analysis of soils and plant material. After helpful discussions at other research institutes, the schedule of tests used at the Macaulay Institute in connection with the Soil Survey (Scotland) has been adopted and the operations tried out in our laboratories. Work on adaptation and selection of methods for analysis of plant material is proceeding.

Analytical work already undertaken has included the determination of total phosphate in some 300 soil samples for the Silvicultural section, and a number of arsenic determinations in wood and bark samples from chemical bark peeling experiments. About 100 soil samples have been subjected to various other tests. Other work of the section included field studies, construction of equipment, and maintenance of a bibliography of analytical methods and papers of special interest in relation to forest soils.

POPLARS

By T. R. PEACE and J. JOBLING

176.1 Populus

DURING THE YEAR under review steady progress has been made in the establishment of varietal trial plots and silvicultural experiments, while older plantings have continued to be satisfactorily informative and have been actively maintained. Planting of the populetum at Alice Holt continued on the same scale as last year, and the testing of clones for their resistance to bacterial canker again formed an appreciable part of the programme.

Varietal Studies

Varietal Trial Plots 232.12

No new areas were started during the year, although a small number of plots were laid down at Ross Priory, Garadhban Forest, Dunbartonshire, for the first time, on a site which had been partially planted with two silvicultural experiments in 1954. Planting was again carried out on a large scale at Cannock Chase, Staffordshire, and at Wynyard Forest in County Durham, while the number of plots in the trial area at Owston, Doncaster Forest, Yorkshire, was considerably increased. Planting also continued at Harling, Thetford Chase, Norfolk, and at Quantock Forest in Somerset. In all ninety-nine plots were planted, representing sixty-one clones.

At nine of the major trial areas a plot of a highly canker-susceptible clone, such as *P. trichocarpa* B.C. or *P. generosa* H, was planted, which, after inoculation of the trees, should become a source of bacterial infection In this way, it is hoped to determine which of the clones under trial are resistant to canker under natural field conditions. Full-scale assessments were started on a few trial areas during the winter.

Varietal Collection

The collection contained 316 clones in December, 1955, as compared with 304 clones the previous year. A number of clones were discarded, while a large proportion of the new introductions are strains of *P. tremula* or of closely related species and hybrids of the section Leuce.

Populetum

Fifty-one additional clones were planted during the winter, making a total of 176 since planting started in 1953.

Silvicultural Experiments 232.4

Eight experiments were planted during the winter, of which four are of long-term duration, making a total now maintained and assessed of thirty-five. A number of experiments planted between 1951 and 1954 have been satisfactorily informative, particularly on age and type of planting stock and on planting treatments, and reports are being written on these. A summary of the latest results, and an indication of the amount of new work on each project is given below.

Kind of Stock

The experiment planted at Penyard, Forest of Dean, in 1955, comparing the behaviour in the field of one-year rooted cuttings raised at different nursery spacings, has again confirmed that one-year plants grown at wider spacings than normal in the cutting beds (18 inch x 18 inch upwards to 24 inch x 24 inch) have a similarly high rate of survival as one-year rooted cuttings stumped and transplanted for one year, and display at least the same vigour as the older type of plant during the first season after planting.

An experiment planted during the past winter at Blandford Forest, Dorset, compares also one-year rooted cuttings raised at different nursery spacings. For the first time, however, stock produced at Alice Holt and at Fenrow Nursery, Rendlesham Forest, Suffolk, has been included, in addition to plants raised at Kennington Nursery, Oxford, where all previous nursery work on this project has been carried out. It must be admitted that the production of satisfactory one-year plants has proved more difficult at other nurseries than at Kennington.

A second experiment comparing the establishment in the field of different sizes of nursery stock of a given age, was planted during the winter at Rendlesham Forest. This, using one-year rooted cuttings of *P. berolinensis*, ranging in size from 3 ft. to 7 ft., is similar in design to the experiment planted in 1954 at Penyard, Forest of Dean. This has shown that although very small plants do not increase in height at the same rate as normal sized planting stock during the first season, their rate of survival is equally as good, and they are as healthy.

Handling of Stock

No additional work has been done on this project during the winter. It is not expected that results from experiments already planted will indicate the correct approach to other problems of handling for at least a further season. So far, complete exposure of tree roots for periods up to forty days immediately preceding planting, has not caused one tree to die out of nearly 300 used in three separate experiments carried out under vastly different conditions; while in an experiment planted in 1955 it has not been possible in the first season to correlate the behaviour of the plant in the field with its previous heeling-in treatment. These treatments included the heeling-in of the plants in water-saturated soil and the immersion of roots in water, both for periods of up to forty days, as well as the more conventional methods of heeling-in.

Methods of Planting

No further work has been carried out on planting methods, but a second experiment has been done on the use of explosives, and an experiment has been laid down at Rendlesham Forest on the use of a post-hole borer for making planting pits. The second "explosives" experiment was planted during the winter at Cannock Chase, Staffordshire, where gelignite was used to blow out planting holes; the quantities of explosives used were again 1.6 oz., 4.0 oz. and 5.6 oz. Firing was done electrically, blowing twelve holes simultaneously. This was found to be rather more convenient and slightly faster than by using safety fuse.

In the 'post-hole borer' experiment, a 9 in. auger was used to make the pits and, working in a peaty-alluvial soil, it was found that the rate of preparing the holes was about half that for normal hand digging.

Spacing in Plantations

The fourth experiment in this project was planted at Doncaster Forest, Yorkshire, during the winter, using a clone of *P. serotina erecta*. The growth of poplar in this instance is being compared at four spacings, namely twelve, eighteen, twenty-six and thirty feet, with a thinning treatment applied in plots at the twelve-foot spacing, and both a thinning and no-thinning treatment to plots at eighteen-foot spacing.

Use of a Forest Tree Species as an Understorey in Poplar Plantations

An experiment planted at Mildenhall Woods, Suffolk, is the second in the project, and here the growth of poplar at a spacing of twenty-five feet by twenty-five feet with an understorey of alder, is being compared with the growth of pure poplar at the same spacing. There is some evidence, on the continent of Europe, to show that alder planted beneath poplar has a beneficial effect on the growth of the latter.

Pruning for Timber Quality

Two experiments have been planted during the winter, one at Cannock Chase and the other at Rendlesham Forest, to which pruning treatments will be applied during the current, and in subsequent seasons. In the first, which covers an area of six acres and contains 600 trees, the treatments are concerned with the time of starting pruning, the periodicity of pruning and the height to which pruning can advantageously be carried. In the second, which is less than half the size, the treatments are on time cf starting pruning, comparing the effects of pruning (i) in the first season, (ii) during the establishment period and (iii) after the trees have become established.

Nursery Experiments

Raising Plantable One-year Rooted Cuttings 232.32

As mentioned above in the section on Kind of Stock, work on the spacing of cuttings has been extended to Alice Holt and Fenrow nurseries. Here no beneficial results were obtained last season by inserting the cuttings at wide spacings, and at neither nursery was plantable stock produced; whereas at Kennington nursery, for the past five years, there has generally been an improvement in quality with increase in spacing, and the majority of the plants have been suitable for planting out. The spacings are fifteen by eighteen, eighteen by twenty-one, and twenty-one by twenty-four inches, the first being that normally used in Research poplar nurseries.

It is uncertain whether the beneficial effects of wide spacing are only obtained in certain soil types, and to clarify last season's results the same experiment has been re-planted again at Fenrow and Alice Holt, and for the first time at the Bush nursery, near Edinburgh.

Manuring of Cutting Beds

The experiment at Alice Holt and Nagshead (Forest of Dean) nurseries, on the use of nitrogen, phosphate and potash fertilisers, as alternatives to compost, has so far given no positive results, and the work at both nurseries is continuing.

Mulching of Cutting Beds

An experiment comparing the effectiveness of different levels of a mulch for suppressing weed growth in the cutting beds, has been laid down during the winter at Nagshead and the Bush nurseries. It is hoped that by applying a mulch immediately after cutting insertion, it will not be necessary to weed at any stage during the growing season.

Distribution of Cuttings

During the past winter over 1,500 cuttings of about fifty clones have been sent to research workers in Canada, Germany, Greece, Holland, Sweden and Turkey, as well as to persons interested in poplar cultivation in this country.

Cuttings of the standard varieties, namely *P. eugenei*, *P. gelrica*, *P. robusta*, *P. serotina* and *P. serotina erecta*, have again been widely distributed to private estates and trade and Forestry Commission nurseries, though in reduced numbers compared with the past two years. The following table gives the number of cuttings despatched in each of the years 1952 to 1956.

Annual Sale of Poplar Cuttings

	1952	*1953*	*1954*	*1955*	*1956*
Forestry Commission	4,900	17,036	22,950	26,700	12,750
Trade and Private Estates	10,730	10,200	16,450	5,425	10,900

Since the distribution system began in 1949 the following number of cuttings of each variety have been despatched from Alice Holt:

P. eugenei 3,300; *P. gelrica* 29,650; *P. robusta* 47,870; *P. serotina* 44,610; and *P. serotina erecta* 52,710, a total of 178,140 cuttings.

Bacterial Canker Investigations

Inoculation of long cuttings of clones under trial was carried out this spring at Fenrow nursery, while during the year earlier plantings have been maintained and assessed at Mundford nursery, Thetford Chase. Because the latter nursery is now completely filled, future work of this type will be carried out at a nursery now in the course of preparation at Barton Mills, Mildenhall Woods, although until this is ready canker work will be centred at Fenrow. It is hoped to start publication of the results after the next assessment due to take place in June, 1956.

The natural infection trials have been maintained at Bretton Park and Parlington Park, both in Yorkshire, in which the clones under trial are planted between rows of diseased trees, while plots of canker-susceptible varieties have been planted at nine major trial areas—as mentioned above.

FOREST GENETICS

By J. D. MATTHEWS and A. F. MITCHELL

The General Programme of Improvement 165.3 : 232.311

Two main methods are being used to improve certain of the important forest tree species in Britain:

1. The selection and direct use of desirable varieties and individuals already existing in the forest.

2. The utilization of hybrid vigour or heterosis obtained by cross breeding within species (intra-specific hybridization) and between species (inter-specific hybridization).

These methods are being used to improve Scots pine, European and Japanese larch, Douglas fir, beech and certain other species. The aim of selection and breeding in these species is to obtain varieties (cultivars) showing increased vigour of growth, improved growth habit, better adaptation to adverse conditions such as drought, frost, snow and exposure to wind, increased resistance to disease and insect attack and improved timber quality.

Work is in progress on the following projects:

(1) A survey of the existing woodlands and plantations in Britain, to study the natural variation exhibited by each species, to locate the best possible seed sources for current planting programmes and to select outstanding individuals (plus trees) for use either directly or as parents in breeding work.

(2) The production, by vegetative propagation, of clones from the plus trees for inclusion in Tree Banks (collections of plus trees), Tree Shows (trials of the genotype of plus trees) and Seed Orchards, and also for direct use in the forest.

(3) The testing of the progeny of plus seed sources, and the testing of plus trees by clonal and progeny trials.

(4) The formation of Seed Orchards using clones derived from plus parent trees to produce seed of Scots pine, Douglas fir, the larches and beech; and the use of these seed orchards for the further improvement of the species.

(5) The use of inter-specific hybridization between selected individuals of the larches and pines and the formation of seed orchards with clones of the successful combinations to produce seed of the first generation hybrids.

(6) A study of the techniques of tree breeding and in particular the development of improved methods of vegetative propagation; the study of the biology of flowering and fruit formation; the trial of methods of stimulating flowering and the development of methods of controlled pollination.

(7) A study of methods of controlling seed origin and quality.

A summary of the progress made during the year now follows:

Survey of Seed Sources 232.311.2

The location of suitable seed sources for current planting programmes continued during the year. A survey of England, covering all species in common use, was begun during the summer of 1955. Seventy-two woodlands and plantations in the North West Conservancy were assessed and classified as suitable or unsuitable for seed collection. The total area of plus and normal seed sources in North West England amounts to 428 acres at present.

The study of the natural variation exhibited by European and Japanese larch and Douglas fir was continued.

Selection of Plus Trees 165.62

The selection and propagation of outstanding phenotypes (plus trees) was continued. The total number of plus trees of all species which have been marked and recorded is now 2,002. Over one-quarter of these are Scots pine, and there are more than 300 plus trees of both European larch and Douglas fir.

Vegetative Propagation 232.328

Grafting, the rooting of cuttings, and layering were again employed to raise clonal material for inclusion in tree banks, tree shows and seed orchards. The final total of grafts attempted during the spring of 1955 was 11,596, and the total of successful grafts surviving to the spring of 1956 was 8,038, representing 386 parent trees. The overall success was sixty-nine per cent, while that for the larches was seventy-seven per cent—an improvement on the previous year despite bad drying winds in April.

Ninety per cent of the grafts were done at the three propagation centres—Alice Holt (Hampshire), Grizedale Forest (Lancashire) and the Bush Nursery (Midlothian). The remainder were done in existing tree displays or on seed orchard sites.

The propagation of plus trees of *Thuja plicata*, Norway spruce, Sitka spruce and other species which can be propagated by cuttings, was continued. Four additions were made to the collection of clones of *Cupressocyparis leylandii* originating from various parts of Britain.

Formation of Tree Banks 271

Collections of clones derived from plus trees are being built up and good progress has been made with the larches, Scots pine and Douglas fir. These tree banks will together eventually form a National Collection of plus trees. Permanent sites were obtained and prepared during the year at Newton Nursery, Morayshire, for Scots pine and Douglas fir and at the Bush Nursery for European larch. A total of 138 clones of European larch and thirty-nine clones of Japanese larch are available for planting on the Bush site.

Testing the Plus Trees 232.1

The establishment of a large-scale replicated clonal trial, which will contain forty-two clones of Scots pine, European larch and Douglas fir, was continued at Shouldham Forest, Norfolk. Other sites for similar trials were selected.

The raising of plants for progeny trials was also continued. Seed from thirty-one plus trees of Scots pine was sown and two-year seedlings representing more than ninety plus trees were lined out at Alice Holt. The progeny of nineteen plus trees and four seed sources of the larches were planted out in Alice Holt Forest during the spring of 1956.

Breeding 165.4: 232.31

Seed orchards of Scots pine, European larch, Douglas fir and beech are being formed both to produce seed and provide a means of further improvement of these species. Work is in progress at eleven sites totalling 120 acres. Three of these sites, i.e. those at Alice Holt, Rendlesham Forest, Suffolk and Drumtochty Forest, Kincardineshire, are being used for small experimental seed orchards where techniques of management are being tested. The seed orchards on the other areas are on a much larger scale. The planting of the Scots pine and Douglas fir seed orchards at Ledmore, Perthshire, and the beech seed orchards at Hemsted, Kent, and Whittingehame, East Lothian, are now well advanced. Planting is also in progress on two other sites, and ground preparation was begun at three places.

Crosses between selected Scottish and Swedish Scots pines were made at Alice Holt during the spring of 1955.

Seed orchards composed of clones of European and Japanese larch are being planted to produce seed of the F_1 hybrid larch *Larix eurolepis.* Work is in progress at five sites totalling twenty-eight acres, and planting is complete or well advanced at Newton Nursery, Morayshire, Mabie Forest, Dumfries-shire and Grizedale Forest, Lancashire.

The grafted seed trees in the seed orchard at Newton flowered well in the spring of 1956 (most probably because of the good summer of 1955). Although they varied in their flower production, most of the clones were very fruitful and five-year-old grafts of Japanese larch No. 12 were each bearing 300 to 400 cones. Four-year-old grafts of Japanese larch No. 41, five and a half feet tall, were bearing up to 200 cones. Male flower production was generally good, but the European larch clones were less prolific than the Japanese larches.

The first large-scale controlled crossing programme was attempted at Newton. The objects were to obtain sufficient progeny to test all the possible crosses in the seed orchard; to determine the degree of self fertility of each parent clone, and to test as many other combinations of parents as possible using clones in a nearby tree bank of larch. The total number of female flowers isolated and pollinated was 5,031, representing 115 cross and 19 self pollinations. Thirty-six of the crosses were made reciprocally. The seed will be available for sowing during the spring of 1957.

The Techniques of Tree Breeding 232.311.3:181.8

The study of methods of rooting cuttings of Scots pine, the larches and Douglas fir continued at Alice Holt. An experiment was begun in July 1955 to test nine different methods of frame management, four rooting media and the "mist" method of propagation used for *Citrus* cuttings in the United States. During the period under review a few cuttings of Douglas fir, larch and Scots pine had rooted.

London plane, *Platanus acerifolia,* and Leyland cypress, *Cupressocyparis leylandii,* were successfully propagated by layering at Alice Holt and Grizedale.

The use of polythene film as an aid to propagation was extended. Polythene film is used as packaging material for the transport of scions and grafted plants and as individual protection for top worked grafts of various species.

Phenological observations were continued during the year. 1955 was a very poor year for flowering and fruit production—as was to be expected after the unfavourable summer of 1954. 1956, on the other hand, is outstanding for the abundance of flower buds of the majority of species, the summer of 1955 having been very favourable to the initiation of flower primordia.

A trial of partial girdling of the stems and application of fertilizer to the ground in a twenty-eight-year-old plantation of Corsican pine at Sherwood Forest, Northamptonshire, was assessed in 1955. The application of phosphate and potash together appreciably increased the percentage of trees bearing cones, but had no significant effect on the number of cones per tree. The application of nitrogen to plots already receiving phosphate and potash offset this increase. Applications of phosphate alone or of potash alone, significantly or appreciably reduced both the percentage of trees bearing cones and the number of cones per tree.

In this trial the partial girdling treatment very significantly increased both the percentage of trees producing cones and the numbers of cones produced. There were no significant interactions between the effects of the girdling treatments and the effects of the fertilizer treatments on the percentage of trees producing cones, or the numbers of cones produced.

An experiment on flower induction in the larches established in 1953 in a six-year-old plantation of Japanese larch at Alice Holt compared three methods of pruning separately and in combination. The treatments were: topping the trees at eight feet; removing smaller branches and favouring the larger branches; and removing the axes of the branches as they extend in June. Assessments in the spring of 1956 showed that favouring the larger branches was the best treatment. Nine-year-old Japanese and hybrid larch treated to form espaliers produced a great density of male and female flowers.

Equipment for large-scale pollination both on small grafted seed trees and on large standing trees in the forest was developed during the year.

The number of enquiries dealt with during the year was 104, of which 42 came from Commission sources, and 62 from members of the public.

STUDIES OF MANAGEMENT, GROWTH AND YIELD

By Dr. F. C. HUMMEL

52, 56, 61, 905

In previous *Annual Reports* of the Research Branch, the section on studies of Growth and Yield opened with a discussion of sample plot work. This year, however, Forest Management has been placed first in order to indicate the importance which this subject has assumed.

Forest Management

The major problem of the year was to seek a new approach to the old question of finding the best method of enumerating the growing stock of a forest for working plan purposes. Various sampling methods are available, but almost invariably a sampling fraction which will give adequately precise results for the forest as a whole will give insufficient information on the growing stock in individual stands or compartments. On the other hand, a sampling fraction sufficiently large to give adequate information compartment by compartment is, in a sense, wasteful, because the results for the forest as a whole will be unnecessarily accurate.

Our new approach to the problem is an adaptation of what we have been doing in the census of woodlands for a number of years. The basic idea is to obtain the volume estimate for the forest as a whole by measuring an objective sample that will give the required degree of precision; and to supplement this sampling by subjective visual estimates of the growing stock stand by stand. The sum total of the visual estimates is compared with the volume calculated from the sampling, and if there is a discrepancy the individual visual estimates are corrected by applying a uniform percentage adjustment to each. Provided that the stands are small and uniform, a further check on the visual estimates is provided by comparing the measured volume of each plot with the visual estimate for the stand in which it lies.

In spite of these checks success depends very largely on the skill and experience of the enumerators in the art of estimating by eye. The checks merely give an indication of the probable precision and bias of the individual visual estimates, but they can do little to improve bad estimates.

The method was applied with very promising results to Inverliever Forest which has an area of about 2,500 acres, consisting of an intricate mosaic of about 900 stands. The first step was to revise the stock map with the help of aerial photographs which greatly speeded up the work. Each stand was classified according to a procedure similar to that used in the Census of Woodlands. The estimates of volume in each stand were based on basal area determinations by the relascope method, and on a limited number of height measurements. The height measurements also enabled quality class according to the yield tables to be estimated. This was of some importance in the older age classes, because the extent of the area in the first and second quality class will largely determine when fellings should start and at what rate they should proceed. The objective volume estimate was obtained from a stratified random sample of one-tenth acre plots, sampling being at the rate of one plot for every 100 acres. This sampling fraction is much too low for giving a precise estimate, even for the forest as a whole, but was accepted when it was found that in each stand where there was a plot, the visual estimate agreed very closely with the measured volume of the plot; furthermore, the total visual estimate of 5.3 million hoppus feet for the forest as a whole agreed very closely with the volume of 5.2 million hoppus feet calculated from the plots.

The total cost of the survey, including the revision of the stock map and the computation of results, was about 2s. 6d. per acre. This figure includes salaries, subsistence and transport, but excludes the cost of supervision and other overhead expenditure. The details of procedure are undoubtedly capable of considerable improvement, and they will have to be adapted to suit varying local conditions; but our preliminary results do suggest that we have found a promising approach to a problem which is steadily gaining in importance. Further enumerations on the above lines are in hand.

This work on working plan enumerations is being followed up by estimates of increment in what may be regarded as 'permanent sample compartments'. The use of compartments as sampling units causes certain difficulties but has the great advantage that record keeping is simplified and that quite a number of possible sources of error are eliminated. The increment is obtained from successive enumerations of the growing stock and from the recorded volume of thinnings removed. The enumeration work is reduced to a minimum by applying to the standing crop the "tariff" method of measurement which is already widely used for determining the volumes of thinnings before they are felled. The details of procedure have been evolved and are about to be tested in practice.

The problem of improving the very abnormal age class distribution of many of our forests was mentioned in last year's *Annual Report*. This problem has received further attention and a short paper has been submitted to the International Union of Forest Research Organisations, indicating briefly the various methods by which we think the problem can be solved. They are: grouping several forests to form a single felling series; replacing failed plantations and underplanting some others; taking advantage of differences in rate of growth; premature and delayed fellings; and variations in the thinning treatment. The main object of the paper is to stimulate an exchange of views and ideas on the subject as a preliminary to more detailed work.

Another paper was prepared on the subject: "The possibility of wider espacements and shorter rotations for conifer plantations in Great Britain". This paper summarises a talk given to the Oxford University Forestry Society and has now appeared in the Journal of that Society. (*O.U.F.S. Journal* 1956).

The general question of working plan procedure was also studied and the Mensuration Officer attended some of the meetings of the Committee appointed to submit recommendations on this subject.

Forecasts of production for individual regions and specified categories of produce took up less time than in the previous years; this is because the Conservators of Forests are now in a position to prepare most of these forecasts from their own records. This development must be regarded as very satisfactory.

Census of Woodlands

During the year ending March, 1956, four counties with a woodland area of 184,000 acres were resurveyed. They are, the North and East Ridings of Yorkshire, Hertford and Montgomery. This survey not only involved the complete census of all woods of five acres and over, but also the sampling surveys of woods between one and five acres in individual extent, and of hedgerow and park timber. In addition to the information obtained on areas and volumes, details of ownership were recorded, and a survey of fence lines carried out.

The object of the fence line survey is to give some idea of the amount of timber used annually for fencing. The length of fences either wholly or partially composed of timber varies from region to region, and too few counties have as yet been surveyed for any conclusions to be drawn for the country as a whole. The results to date, however, suggest that the volume of timber contained in these fences must be considerable, and also that the greatest lengths of boundaries per square mile of land area are to be found near towns. The results for four counties are summarised in Table 12.

Estimated length of field and other boundaries

Table 12

County (a)	Area of County square miles (b)	Average length of boundary per square mile. (c)	Proportion of col. (c) composed wholly or partially of timber (d)
		(chains)	
Ross & Cromarty	2,533	115	74%
Yorkshire, North Riding	2,128	1,115	20%
Yorkshire, East Riding	1,172	1,052	28%
Hertfordshire	632	1,717	18%

Ross and Cromarty has the very low figure of 115 chains per square mile. The two Ridings of Yorkshire have an average ten times as great as Ross-shire, and can be considered as being fairly typical of the predominantly agricultural regions with mixed upland and lowland farming. Hertfordshire has an average which is 15 times as great as Ross and represents a county of mixed urban and rural character.

The analysis of ownership in the counties surveyed since census revision began in 1953 has started to reveal some interesting trends. The results are summarised in Table 13.

Table 13 *Analysis of Ownership of Woodlands*

County	Area for which ownership was established	No. of owners	Average acreage per owner
Cambridge	7,007	252	28
Berkshire	45,494	1,000	45
Hereford	39,756	882	45
Flint	8,378	176	48
Huntingdon	6,344	128	50
Rutland	3,170	48	66
Yorks, East Riding	15,363	208	74
Yorks, North Riding	47,771	463	103
Kincardine	20,176	125	161
Angus	43,828	255	172
Ross and Cromarty	59,939	171	350

The average acreage per owner in the seven English counties ranges between 28 and 103 acres; and in the three Scottish counties between 161 and 350 acres. Flint, with 48 acres per owner, is the only Welsh county for which figures are at present available, but a preliminary analysis of the field data for Montgomery suggests that the acreage per owner will be similar.

Sample Plots

The revised code of sample plot procedure, mentioned in last year's *Annual Report*, has been completed, and is being prepared for publication. The new procedure has been in operation since January, 1956. A summary of the number of permanent sample plots established, re-measured and abandoned during the year is given in the Table 14, below:

Table 14 *Permanent Sample Plots*

	England	Scotland	Wales	Totals
Plots in being, 1st April, 1955	328	221	108	657
Plots established 1st April, 1955 to 31st March, 1956....	27	4	18	49
Plots written off (blown, felled, etc.)	—	—	—	—
Plots previously written off—reclaimed	—	2	—	2
Plots in being 31st March, 1956	355	227	126	708
Plots re-measured 1st April, 1955 to 31st March, 1956....	106	52	38	196

Twenty-one of the new plots were established in spacing experiments, and fifteen were established in the Forest Plots at Bedgebury. Of the other new plots the most noteworthy are perhaps two plots in Dorset, established in stands of Corsican pine and Sitka spruce, which had been awarded a certificate of merit in the Royal Counties Show Woodland Competition. The Sitka spruce plot is of Quality Class I, in spite of the comparatively low rainfall of twenty-six inches per year, while the Corsican pine plot is above Quality Class I of the Revised Yield Tables for Conifers in Great Britain. A new sample plot in a forty-four-year-old stand of Douglas fir in the Forest of Dean is also above Quality Class I, and is the fastest growing plot of Douglas fir we have. The tallest trees in the plot are 115 feet high, and one tree removed as a thinning contained a volume of just under 100 hoppus feet over bark.

A series of three plots thinned to B, C/D and E grades respectively was established in *Pinus contorta* at Caio Forest; this is our first thinning series in that species in Wales. The other seven new plots were in broadleaved species; three in oak, one in hornbeam, two in red oak and one in sweet chestnut. The latter, having reached a height of 77 feet in 52 years, compares favourably in height growth with Quality Class I Oak.

Among the plots remeasured during the year were the Norway spruce plots at Bowmont Forest, Roxburghshire, in which the D grade plots still show a higher volume production than do the plots thinned to LC, C and B grades. The number of trees per acre in the D grade plots is now reduced to one-sixth of that in the B grade plots.

Yield Tables and Volume Tables

A provisional yield table for *Tsuga heterophylla* has been prepared, based on data from permanent and temporary sample plots. This is the first of the series of provisional yield tables that are being prepared for those less widely planted but promising conifers for which, as yet, no yield tables are available in Britain. Four quality classes are distinguished with top heights of 100, 90, 80 and 70 feet at fifty years. Quality Class I is thus equivalent in height growth to Quality Class II of Douglas fir and Sitka spruce. There is a suggestion that the height growth of *Tsuga* may not drop off as rapidly as in these other two species, but this suggestion must be treated with great reserve as we have very few data on *Tsuga* stands over forty years of age. The total volume production of *Tsuga* Quality Class II at fifty years, shown at 10,730 hoppus feet in the new yield table, is similar to that of 2nd Quality Douglas fir and slightly lower than that of 2nd Quality Sitka spruce.

The wider application of the general tariff tables has been studied. Hitherto their use has been confined mainly to the estimation of the volume of thinnings before they are felled. During the year two methods of using the general tariff tables for estimating standing crop volumes in coniferous plantations have been developed:

(i) The tariff number of the standing crop may be determined from that of the thinnings. It was found that except where thinnings are particularly light the tariff number of the thinnings may safely be applied to the main crop. The resulting volume estimates may be slightly low (usually about five per cent) but the error is consistent so that estimates of increment based on these volume estimates may be regarded as sufficiently reliable in practice.

(ii) The tariff number may be determined from the top height of the crop. A report on the results of this investigation is in draft. In another paper, which has been published in the *Forstwissenschaftliches Zentralblatt* (Vol.

75, No. 3/4 1956) under the title: "Die Massengerade als Grundlage von Einheitstarifen für den Altersklassenwald" the tariff tables are briefly discussed and compared with those of Loetsch.

Instruments

The new version of the Spiegel relascope calibrated in British units of measure has been tested. Preliminary results indicate that this is a useful addition to the range of mensurational instruments, particularly for working plan enumerations. Useful estimates of height and girth as well as of the basal areas per acre can be obtained with it. The reflectorscope, a simpler type of relascope developed in Australia, has also been tested.

A paper was submitted for consideration at the forthcoming conference of International Union of Forest Research Organisations at Oxford; it suggests that there is a need for international co-operation in the collection and publication of information on instruments used in forest mensuration. The object is to make it easier for foresters to find out what instruments are available, and to obtain reliable reports on their performance.

Statistics

The statistical work of the Mensuration section was severely handicapped by the transfer on promotion of the officer, who was responsible for this work, to another Government Department. No successor had been appointed by the year ending March, 1956, but an assistant forester has dealt with quite a large proportion of the more urgent routine designs and analyses.

The Mensuration Officer was appointed to a joint F.A.O. and Economic Commission for Europe Working Party, the main object of which is to prepare a minimum long-term programme of forest and forest products statistics.

Other Work

Lectures and thinning demonstrations were undertaken by various members of the section.

The field parties were again responsible for measuring and getting ready for despatch supplies of timber for testing at the Forest Products Research Laboratory at Princes Risborough. Staff was again made available to the Deputy Surveyor of the Forest of Dean for the enumeration project referred to in previous reports.

Moisture content and specific gravity determinations were made on various batches of material supplied by the Utilisation Development Officer, for whom we also collected some preliminary data on the growth and yield of horse chestnut.

Enquiries answered during the year totalled 250, about one-third being from members of the public.

FOREST PATHOLOGY

By T. R. PEACE and J. S. MURRAY

443

WORK ON FOREST DISEASES continues to be spread over a wide range of subjects, to many of which only summary treatment can be given. The work carried out during the year is summarised below:

Group Dying of Conifers

Fructifications of *Rhizina inflata* appeared in abundance in groups during the autumn of 1955, being more prolific than in any year previously recorded. Further detailed survey work was carried out in areas of heavy infection, which gave further evidence suggestive of a connection between fire sites, the fungus *Rhizina* and Group Dying. As a result, a note was sent out to Commission forests and private estates, where the disease occurs, advising that fires should be restricted to a limited number of sites, each surrounded by a trench.

A large number of fire sites are now under observation to test the theory that they constitute a colonising point for *Rhizina*. From the survey there is also evidence that the advance of groups may be halted by ditches, so that surrounding a small, recently started group by a drain may be effective in confining it.

Top Dying of Norway Spruce

Further observations have supported the explanation of top dying as being primarily due to a disturbance of the water balance in the tree by normal drought, by thinning, or by the removal of shelter, followed by needle infection by *Rhizosphaera kalkhoffii*. Intensification of the damage in affected stands has been reported following the dry summer of 1955. A moisture content analysis of stems from one area showed a significantly lower value in affected trees, as compared to healthy ones.

Resin Bleeding of Douglas fir

The cause of this disease is still unexplained, but from observations it appears unlikely that it is caused primarily by fungal infection of the stem. The breakdown in the cortex suggests a physiological cause. Experiments are in progress to test the effect of artificial drought on Douglas fir. One pot experiment has been set up, and in addition a cover to exclude moisture from a small patch of older Douglas has been erected in an affected stand. The inoculation experiments begun last season have been continued.

Rhabdocline pseudotsugae on Douglas fir

The occurrence of this fungus on Douglas fir of 'Coastal' origin has now been confirmed in other provenance experiments. Arrangements have been made to collect more detailed information from the experiments in the summer of 1956. The degree of occurrence of the other needle fungus of Douglas fir, namely *Phaeocryptopus gaumannii*, will be recorded at the same time.

Dieback of Corsican Pine

Further cases of dying of pole-sized Corsican pine planted at high altitude were seen. *Brunchorstia destruens* occurred, sometimes in abundance, on the shoots, but the site details supported the explanation previously expressed, that the real trouble is the extension of Corsican pine planting beyond the climatic range of the species.

Defoliation of Scots Pine

Survey of one of the forests severely affected by *Lophodermium pinastri* in the spring of 1955, showed a very definite relationship bettween the occurrence of the fungus on young pine plantations and the presence of lop and top under neighbouring recently-thinned pine. The dying branches and tops had acted as sources of infection to the neighbouring young trees.

Later, several outbreaks of quite severe defoliation associated with the fungus *Sclerophoma pithyophila* occurred in East Anglia. No permanent damage has been done, but the affected areas are being kept under observation to see if the attack re-occurs.

Keithia thujina on Thuja plicata

Most of the work on this fungus is now being carried out at Nottingham University and is reported elsewhere. A spraying experiment for the preliminary testing of a range of possible fungicides has been started at Alice Holt.

In the remaining isolated nurseries, which are under observation, no further cases of infection have occurred. It is, therefore, still considered worthwhile to try and keep new and reasonably isolated nurseries free from the disease by bringing in *Thuja* solely in the form of seed.

Individual *Thuja* showing apparent resistance to *Keithia* have been located by the Genetics section, and stocks are being built up so that a seed orchard can be established. In the meantime their resistance is being further tested by exposure to natural infection, and by inoculation at Nottingham.

Meria laricis on Larch

The interesting problem raised by the unexpected occurrence of *Meria* on Japanese and Hybrid larch, as well as on its normal host (European larch), is now under investigation at Southampton University. This work, so far largely of a preliminary nature, is reported elsewhere.

Cronartium ribicola on Pinus strobus

A start has now been made with the establishment of a seed orchard with the vegetative progeny of the *Cronartium*-resistant clones of *P. strobus* received originally from the United States. The test area at Alice Holt, where various five-needled pines and currants, some supposed to be resistant to the disease, are being grown in mixture, has been extended. It is now well infected.

Botrytis cinerea on Young Conifers

Spraying trials of artificially infected beds with a variety of fungicides in common use, have yielded disappointing results. In no case has any substance appeared a likely control, but this may be due to the experimental technique. It is proposed to carry out a further spraying trial this season, employing pre- as well as post-infection spraying.

Death of Groups of Conifers due to Lightning

Observations have been continued on groups of conifers killed by lightning. The symptoms are distinctive, and most cases are readily distinguishable from deaths due to other agencies. It is not considered that lightning is a serious source of loss in our forests, but it is probably commoner than is generally realised.

Decay and Death Caused by Fomes annosus

During the year this subject has become the largest of our pathological projects. Work is being extended beyond the original idea of an investigation of the behaviour of *Fomes* in second rotation crops on infected areas, to include work on stump treatment of thinnings, with especial reference to the possibility of preventing the infection of crops on virgin ground, on economic losses due to *Fomes*, and on the effect of various silvicultural methods on the behaviour of the fungus.

During the year, the first large-scale experiment on the treatment of an infected area to prevent or lessen infection in the second rotation planting has been completed. This covers an area of eighteen acres. Girdling and poisoning were applied as pre-treatments to the existing crop, which was later felled. At this stage additional treatments, including two degrees of stump removal and stump poisoning, were applied before the area was replanted with a variety of species. This experiment was carried out on a Scots pine crop in East Anglia. In this area *Fomes* is important mainly as a cause of death of young pine. Sites have been selected for the same type of experiment, where *Fomes* is present in its more important role as a cause of butt rot.

Survey work has also been done to find areas where stump treatment of thinnings (painting the cut surface of the stumps with creosote or some other substance to prevent the entry of *Fomes*, and its subsequent spread to other trees in the vicinity) can be tried both on an intensive and on an extensive basis. So far, all the work (mainly carried out by Dr. Rishbeth at Cambridge University—see separate report on page 87) has been on pine in East Anglia, but it is planned to extend it to other conifers in other parts of the country, and particularly to places where butt rot, rather than death of trees, is the main *Fomes* problem. This work is being planned in co-operation with Dr. Rishbeth.

Bark Disease of Beech

Observations were continued on numbered plots in several beech stands. These supported the theory that climatic factors are more important in Britain, in initiating bark die-back, than the insect *Cryptococcus fagi*. Typical early symptoms of bark die-back were seen in old trees which were not affected by *Cryptococcus*, following the dry summer of 1955. In plots of beech where *Cryptococcus* has been present for at least five years, no similar breakdown of the bark was seen.

Bacterial Canker of Poplar

Inoculations on the large collection of clones now in the possession of the Research Branch have been continued. The results from year to year are proving more consistent than those of similar work carried out in Holland. Survival has been very satisfactory in the second area for natural infection, which was planted in 1954. Here young plants of various clones have been put in the gaps in a mixed poplar planting some fifteen years old, where several varieties are heavily infected with canker. Probable natural infection has already appeared on a susceptible clone of *Populus trichocarpa*. So far no definite bacterial canker has appeared on the older test planting (1951), where the trees for test were planted in racks cut through heavily infected suckers of *P. candicans*.

During the winter, groups of highly canker-susceptible clones were planted in most of the principal poplar trial areas. Most of these will be inoculated with bacterial slime in the hope that they will later act as centres of infection for the trial plots. This should give a further and more extensive test of resistance or susceptibility under natural conditions to the many clones included in the trials, which are primarily intended to test the growth of the poplars under varying climatic and soil conditions.

Sooty Bark Disease of Sycamore

This disease still continues to abate. It is now getting very hard to find lesions where the causal fungus, *Cryptostroma corticale*, is still active. The fungus was, however, recorded on a felled sycamore pole in Somerset, much further west than any previous known occurrence.

Elm Disease (Ceratostomella ulmi)

Further grafting has been done with the disease-resistant elm stocks received from Holland in 1954 and 1955. It is hoped to have some plants ready for planting out under conditions of heavy natural infection by the winter of 1956-57.

A repeat sampling survey was made in September, 1956. This showed that since the last survey was made in 1949 the disease had made very little advance. The number of elms removed for road widening, safety, housing site clearance and other similar purposes completely outweighed losses due to the disease.

Wound Protectants

A preliminary assessment has been made of the experiment on wound protectants, which was designed mainly to compare various bituminous paints with white lead paint. After three years, comparatively few substances remain as a complete cover, and decay is already apparent in some of the wounds. A few substances, however, are certainly worthy of further tests.

Discussion

Pathologically the year has not been a very eventful one. The appearance of *Sclerophoma pithyophila* locally as a major defoliator of Scots pine is interesting. It is not a new fungus to the country, but has not hitherto assumed a major role. Drought crack again appeared, particularly in various *Abies* species, following the dry summer of 1955. Its last widespread appearance was in 1947. An unusually intense occurrence of winter frost crack was observed in a poplar plantation in Norfolk. This occurred in the moderately cold winter of 1953-54, but was primarily brought about by the sudden removal of high dense coppice, which had hitherto sheltered the poplar stems. Every year occurrences such as these serve to illustrate the very important role that climate exercises on the health of our forest trees.

The importance of the physiological, as opposed to the fungal angle, in forest pathology is also illustrated by the fact that derangement of the water balance is under investigation as a possible explanation not only of Top Dying of Norway spruce, but also of Resin Bleeding of Douglas fir. In addition no year passes without records of frost injury to trees in some part of the country. The year under consideration, though relatively free from spring frost injury, had temperatures in February which produced severe winter injury on many of the more susceptible species. The most serious occurrence of lime-induced chlorosis yet observed was seen during the year, affecting young Scots pine planted on a chalk soil.

On the other hand we are dealing with a number of diseases including *Rhabdocline* on Douglas fir, *Keithia* on *Thuja*, *Cronartium ribicola* on Weymouth pine, *Fomes annosus* on conifers, and bacterial canker of poplar, where the fungus or bacterium is certainly the primary agent, though climate or soil may greatly affect the degree and nature of attack.

Enquiries tend to form an ever increasing part of the work of the section. Some of these can be dealt with very quickly, while others tie in with projects already in progress, but many lead to minor investigations of their own. However, apart from the aid given to the enquirer, they all add to our still very incomplete knowledge of the pathological situation in Great Britain, and may be said to form an essential part of the work of the Research Station, as well as an essential service to the forestry public. Altogether 281 enquiries were dealt with, 151 being from private sources and 130 from the Forestry Commission.

FOREST ENTOMOLOGY

By DR. M. CROOKE and D. BEVAN

The Pine Looper, Bupalus piniarius L.

Pupal Survey 453

The 1955-56 pupal survey covered all the forests mentioned in previous *Reports* with the exception of a few very small units in the East (Scotland) and North-East (England) Conservancies where sampling has been discontinued. The approximate total area now surveyed each winter, using the standard sampling method, is 86,000 acres. This area will, of course, increase in the future as more of our pine plantations reach a stage of development vulnerable to looper attack.

It was thought that the warm, dry summer of 1955 would prove favourable to the development of pine looper populations, and that consequently high population indices might be recorded in many areas in the course of the survey. This has not, in fact, proved to be the case. In most areas the population levels remain low, with counts of two or fewer pupae per square yard, although a few of the compartment means slightly exceed this figure. There are some exceptions to the above rule, none of which, however, is giving rise to any immediate concern. For example, on a private estate in the Moray coast region one compartment had an average of 17.2 pupae per square yard. Tentsmuir Forest in Fife returned two compartment means of 7.6 pupae per square yard and the overall average about 0.3 pupae per square yard. Slightly more disturbing is the indication of an upward trend in the East Anglian district where figures in previous years have been uniformly low. At Rendlesham the highest compartment mean is 8.2 pupae per square yard, as opposed to last year's 3.2 pupae per square yard; and at Tunstall the highest compartment mean is 14.0 pupae per square yard as opposed to last year's 2.8 pupae per square yard. Generally, the counts in the main Thetford block are still very low, but the highest compartment mean in the Elveden beat is now 10.2 pupae per square yard as compared with the previous year's 1.4 pupae per square yard.

Of particular interest, in following the recovery of the pine looper populations after the aerial spraying in 1954, are the counts from Cannock Chase and Culbin Forests. In both areas the populations are still remarkably low. In the Cannock Chase forest area thirty-five compartments were surveyed. Sixteen of these yielded zero counts, and there were seven with 0.2, four with 0.4, four with 0.6, one with 0.8, and three with 1.2 pupae per square yard. At Culbin, twenty-seven compartments were surveyed. One of these gave an average of 0.2 pupae per square yard whilst the remainder had zero counts.

Study Plot

After the recent exceptional occurrences the studies on the pine looper are now reverting to their original main theme—namely, that of attempting to define and assess the factors operating on the population dynamics of the species. For this purpose a study plot, twenty acres in extent, has been established in Compartment 128, in Corsican pine planted in 1926, of the Elveden beat, Thetford Forest, and in this intensive investigations are being carried out. The basis of this work is the detailed and accurate sampling of the population density at all stages in the life cycle, and at present most of the effort is being devoted to the development of suitable sampling techniques. It is hoped to establish a number of similar plots in other localities if acceptably accurate and sensitive sampling methods can be devised.

Laboratory Studies

Laboratory studies on the pine looper were directed, this year, towards determining the relationship between female pupal weight and fecundity; and to collecting data on larval development. The first of these topics is discussed in some detail elsewhere in this report (page 155); the second yielded some interesting results which can be briefly described here.

The main object of the study was to determine the number of instars passed through during larval development. Previous authorities consider that normally five instars occur, but that under exceptional conditions only four are necessary. Analysis, based on a presumption of Dyar's Law, of a long series of head capsule measurements, had indicated (see 1955 *Research Report*) that field populations of *B. piniarius* in Britain in 1954 developed with only four larval instars. The laboratory study in 1955 involved the rearing of 150 individually caged larvae under comparable but not controlled conditions of temperature, humidity and food supply. The majority of the individuals passed through five instars, but small numbers of both four and six instar development types occurred. The latter condition has not previously been reported. One practical point which has already emerged is that if populations of mixed development types occur in nature, as they have done in the laboratory, it will be impossible on the basis of head capsule measurement alone to distinguish accurately between third, fourth fifth and sixth instar larvae.

Parasites of the Pine Looper

The annual surveys of pine looper density have indirectly yielded information about the distribution and the relative abundance of the more important parasites of the moth. *Cratichneumon nigritarius* Grav. is the most common species whilst *Heteropelma calcator* Wes. and *Campoplex oxyacanthae* Boie are numerous in some districts.

Preliminary laboratory and field studies were commenced in 1955 with these three species. In the laboratory attention was centred on the general features of the biologies of the species, about which little reliable information had been published, and an understanding of which is a necessary precursor to further investigations. Progress with this work has been slow because the species, and particularly *C. nigritarius*, are proving to be most difficult subjects to rear. Some experience has, however, been gained on handling techniques and on the conditions required for successful breeding. Various trapping experiments were carried out in the field and a new and improved trap has been designed for future work.

Insects in the Gale-damaged Areas of North-East Scotland

The Pine Shoot Beetle, Myelophilus piniperda L.

The huge populations of this beetle which developed in 1954 in the blown woodlands have caused serious damage to standing pine crops. The results of the attack are summarised below.

The shoot tunnelling feeding activities of the beetles have produced extremely severe and extensive crown deformation and defoliation of Scots pine of all ages throughout the whole area affected by the gale.

The invasion of the bark of standing trees by the beetles for breeding, which invariably causes tree death, has occurred extensively in the remnants of blown crops where groups and fringes of trees, and isolated stems, have been successfully colonised and thus killed. By contrast, younger plantations adjacent or near to blown areas have in most cases successfully resisted invasion, even where root systems have been loosened by the gale and where leaning trees are present. In some few exceptional cases, however, the combined feeding and breeding activities of the beetles have devastated some younger plantations, and have caused numerous tree deaths. An example of this occurred in the Skillmafilly plantations, composed mainly of seven- and eight-year-old Scots pine, near Methlick, Aberdeenshire. This was a rather remarkable case in that the nearest centre of infection in a blown area was situated some two miles distant from the affected plantation.

Taking the broad view, the breeding damage to standing crops has been on a much lesser scale than might have been expected, particularly when it is remembered that the conditions for attack in the summer of 1955 were most favourable to the beetle in that the very large numbers of beetles produced in the blown woodlands made their attack during a drought season.

The Pine Weevil, Hylobius abietis L.

As in previous years a survey of the development of *H. abietis* populations was carried out in the blown areas by a series of stump analyses. This clearly demonstrated that 1955 was the season of peak emergence.

Stumps from which the trunk had been removed in 1953 had been utilised for two broods, one commencing in 1953 and the other in 1954. Some of the 1953 brood emerged in 1954, but a proportion of these weevils delayed their emergence because of the unfavourable weather conditions of the summer of 1954. They hibernated in the stumps for a second time and emerged in 1955, together with the whole of the 1954 brood.

In all other stumps entry for breeding was first made in 1954, and resulted in a main emergence in 1955. This appears to be the only large emergence to be expected from these stumps, although a small-scale egg-laying in 1955 will produce a few weevils in 1956.

The combined effect of these breeding activities has resulted in populations varying between 9,000 and 76,500 weevils per acre being produced in the blown areas. Generally speaking, the replanting of the devastated areas should be possible in 1957, but attention will have to be paid to the remnants of the large weevil populations which have arisen. By then it is hoped, however, (see p. 71) to have available an efficient and reasonably cheap insecticidal method for the protection of newly formed conifer plantations against weevil attack. With this additional weapon to hand, the presence of even moderately large weevil populations should present no hindrance to successful replanting.

The Larch Bark Beetle, Ips Cembrae Heer.

During the year *Ips cembrae* was discovered for the first time in Britain in twenty-nine localities in Moray, Nairn, Banff and Inverness. It is thought that this beetle entered the country on the post-war consignments of German timber, along with *Ips typographus* L. with which it can easily be confused. The latter species has not become established, but it is assumed that *I. cembrae* has persisted in small numbers until the gale damage provided favourable conditions for its increase. In view of the fairly widespread distribution of the beetle in the north-east of Scotland, and of its high numerical status in some localities, it has to be accepted that there is now no possibility of eradicating this species from Britain.

The continental literature indicates that *I. cembrae* is a serious pest of larch, particularly in drier regions and in drought seasons. Breeding takes place in felled logs, windblown stems or standing trees. The maturation feeding of the adults occurs either as an extension of the breeding galleries or by tunnelling in large twigs. This latter activity causes quite marked crown pruning.

In the British cases shoot tunnelling was an obvious feature of the attacks. It was particularly noticeable because the sprays broken from the crown were often large, the age of the twig at the point of tunnelling being up to eighteen years, and the length of the spray up to twenty-four inches. In one case an average of one tunnelled spray per square yard of forest floor was recorded.

although usually the density of infestation was much less than this. Twig boring has been observed on European, Japanese and Hybrid larches, and crops varying in age from eight to two hundred years have been attacked.

In only one locality has *I. cembrae* succeeded in breeding in and killing standing trees. This occurred in a European larch wood of about forty-five years of age where blown stems had provided a breeding reservoir. Many of the standing trees which were invaded had very small crowns, but some others were of normal vigour. Drought conditions had certainly assisted in allowing breeding, and it was noticeable that some stems had been invaded only on their exposed faces where cambial scorch was operative, whilst the shadier aspects were still green and alive and resisting colonisation.

Trials of Insecticides against Pine Weevil, Hylobius abietis L.

Further experiments have been conducted on the use of various insecticides to protect newly formed conifer plantations against the attacks of the pine weevil, *Hylobius abietis*. During the current year five trial areas, each of 2½ acres, were treated and kept under observation. The insecticides used—DDT and BHC, alone and in combination, and dieldrin—were applied as either dusts, sprays, or dips at varying concentrations. With most of the treatments the results indicate that one application gives good protection for the whole season and reduces weevil damage on heavily infested sites to an acceptably low level. There is also an indication that, with dusts, there is a carry-over of protection to and through the second season. Work continues on this topic, and it is hoped to make definite control recommendations at the end of the 1956 season's experimentation.

Studies on Conifer Sawflies

The larch sawfly survey, which was allowed to lapse in 1954 because of pressure of other work, was again carried out in 1956, and will in future be biennial. The area surveyed was increased by the inclusion of a number of forests in the South-West England Conservancy. In these the incidence of sawfly occurrence was very low. Elsewhere the three common species, namely *Pristiphora erichsoni* Htg., *P. laricis* Htg., and *Anoplonyx destructor* Bens., were found to be widespread but not at high population levels, with the following exceptions.

At Radnor Forest about one hundred acres of Japanese larch was heavily infested by *A. destructor* and showed severe defoliation. The same species had also severely defoliated about thirty acres of Japanese larch at Clashindarroch Forest, whilst at Drumtochty Forest severe and often complete defoliation of rideside trees was present over large areas. Fairly high populations of *A. destructor* also occurred at Craigvinean Forest, on the Athol Estates between Dunkeld and Blair Athol, and at Kirroughtree Forest.

The laboratory studies on a number of pine, larch and spruce feeding sawflies were continued.

Fogging Machines

A number of machines which emit insecticidal fogs have recently been designed, and one of these—TIFA (the Todd Insecticidal Fog Generator) has for a number of seasons been used with great success against some large outbreaks of forest defoliators in Bavaria. The emission of insecticidal fogs is perhaps the only alternative to the aerial application of insecticides in controlling widespread epidemics of defoliators, and according to the Bavarian experience the method compares very favourably with treatment by aircraft, when costs are considered. The technique and the machine are thus of some considerable interest to us.

During 1955 a number of trials were carried out in this country in collaboration with the manufacturers of TIFA, with Insectrol Ltd., and with some members of the staffs of Jeallott's Hill I.C.I. Research Station and Plant Protection Ltd. The tests were made in a block of twenty-two-year-old Scots pine in Bramshill Forest and the normal dosage rate of one pound of DDT in one gallon of oil per acre was applied on each occasion. In the absence of any natural infestation the test subjects used were houseflies, which were caged in the pine crowns at a number of stations throughout the trial area. Assessments of the treatments were made by mortality counts on these flies, by feeding treated foliage to larvae of *Bupalus piniarius* L., and observing resultant mortality, and by obtaining washes from the treated foliage and ascertaining the insecticidal activity of these. Although by visual estimate the treatments appeared to be good insofar as the fog penetrated well throughout the test area and persisted for some time, the results in fact were most discouraging. All the assessments yielded erratic, contradictory, and on the whole poor results. The reasons for this are obscure, and it has been suggested that the wrong formulations were used, or that insecticidal breakdown occurred in the apparatus, but there is no evidence to support either view. Work continues in an effort to clarify the situation.

The Chestnut Weevil, Curculio elephas Gyll.

During the year a consignment of eight tons of sweet chestnuts imported from Italy by a firm of nurserymen in Scotland was found to be very heavily infested by the weevil *Curculio elephas* Gyll. This species, which infests both chestnuts and acorns, is not indigenous to Britain and, although it is by no means a serious forest pest, its establishment here is clearly undesirable. Accordingly, and with the very ready co-operation of the firm involved, immediate steps were taken to disinfest the consignment. Firstly, the seeds were treated with a sheep dip which appeared to be effective in killing the larvae; and secondly, after the seeds had been sown but before they had been covered, an application of DDT at the rate of one pound of DDT per acre in one hundred gallons of spray liquid was made. This latter treatment was extremely effective in killing the larvae as they emerged from the kernels to pupate and complete control seems to have been obtained.

Advisory Work.

109 enquiries were dealt with during the year, 53 originating from Forestry Commission and 56 from private sources.

GREY SQUIRRELS

By M. NIMMO

451.2

INVESTIGATIONS on squirrels were continued under the direction of the Commission's Committee on Grey Squirrels, of which Sir Richard Cotterell is the Chairman, and in co-operation with the Infestation Control Division of the Ministry of Agriculture. The population studies and records of distribution mentioned in previous reports were continued by Mrs. Vizoso, assisted by Mr. F. Courtier.

Information from Questionnaires

Questionnaire forms were again sent to all Commission Forests in 1955, but this time information was sought on red squirrels as well as on grey ones. Table 15, which summarises the results from two such questionnaires, shows the abundance of grey squirrels and the damage caused by them in 1954 and 1955 respectively, on the Commission's properties.

Table 15 *Abundance of Grey Squirrels, and Extent of Damage Caused, in 1954 and 1955*

Conservancy	(1) Total No. of forests or beats		(2) Percentage of forests where Squirrels absent		(3) Percentage of forests where Squirrels scarce		(4) Percentage of forests where Squirrels numerous		(5) No. of forests with squirrels		(6) Percentage of forests with light damage		(7) Percentage of forests with severe damage		(8) No. of forests with light or severe damage	
Year:	54	55	54	55	54	55	54	55	54	55	54	55	54	55	54	55
England: North-East	40	42	50	62	43	36	7	2	20	16	15	19	15	0	6	3
North-West	35	35	51	57	49	43	0	0	17	15	6	13	12	0	3	2
East	48	51	58	61	31	37	11	2	20	20	50	35	0	0	10	7
South-West	46	48	20	27	65	67	15	6	37	35	30	26	11	9	15	12
South-East	35	44	3	14	66	81	31	5	34	38	38	24	18	0	19	9
New Forest	3	13	67	15	0	54	33	31	1	11	100	55	0	0	1	6
Dean	13	13	0	0	54	100	46	0	13	13	69	69	31	0	13	9
TOTAL (ENGLAND)	220	246	35	40	50	56	15	4	142	148	44	34	12	2	67	49
Wales, South	47	55	17	25	66	65	17	10	39	41	31	39	13	5	17	18
North	34	35	44	60	49	31	7	9	19	14	0	7	0	0	0	1
TOTAL (WALES)	81	90	28	39	59	52	13	9	58	55	21	31	9	4	17	19
Scotland: North	51	61	100	100	0	0	0	0	0	0	0	0	0	0	0	0
West	33	45	76	76	21	22	3	2	8	11	38	10	0	0	3	1
South	41	42	100	100	0	0	0	0	0	0	0	0	0	0	0	0
East	43	54	88	96	12	4	0	0	5	2	0	0	0	0	0	0
TOTAL (SCOTLAND)	168	202	92	94	7	6	1	0	13	13	23	8	0	0	3	1
GRAND TOTAL	469	538	55	69	36	36	9	4	213	216	29	30	11	2	87	68
			percentages of column 1								percentages of column 5					

The figures in columns (2) to (4) and in columns (6) and (7) are given as percentages because of the difference in the total number of forests covered in the two years 1954 and 1955.

It will be noted that there is a marked increase in the percentage of forests with no squirrels reported and a decrease in the percentage with numerous squirrels observed.

Table 16, p. 75, gives a summary of those areas with grey squirrel damage where the details of crops were available in 1954-55.

It is interesting to see that several conifer species were reported as having been damaged by grey squirrels, but that sycamore and beech remain the most severely attacked species.

The information collected on red squirrels showed that out of the 538 forest areas 259 reported none, 246 reported them as scarce; and 33 said they were numerous; the latter areas being situated in East England (17 areas); Wales (North 6 areas—South 7 areas), and Scotland (West—1 area, East—1 area and South—1 area). After the return of the 1956 questionnaires it is hoped to have a good deal more information regarding the red squirrel.

Distribution of Squirrels

GREY SQUIRRELS. Of 150 forest areas in which the density of grey squirrels observed in 1955 was compared with that observed in 1954, ninety-six reported it to be less, thirty-five said it was the same, and nineteen reported it to be greater.

Twenty-four areas reporting grey squirrels to be present in 1954 reported them absent in 1955. In 1954, 256 areas out of the 471 reporting stated grey squirrels to be absent; while in 1955, the corresponding figures were 322 out of 538.

In 1955 grey squirrels appear to have spread to Coed Penllyn in Merioneth, St. Fillans in Perthshire, Minard in Argyll, to woods near Selm Muir (Midlothian) and to Hartland in north-west Devon.

RED SQUIRRELS. Of the 538 forests to which questionnaire forms were sent in 1955, 259 were reported to be without red squirrels, 245 were said to have them, but scarce; and in thirty-four areas they were said to be numerous. The forests where many red squirrels were observed lay in the following regions: Norfolk, Suffolk, and Cambridge in eastern England; the Isle of Arran, Wigtown and Fife in Scotland; and Carmarthen, Pembroke, Cardigan, Montgomery, Merioneth and Radnor in Wales.

It is interesting to note that in 1955, 279 forest areas reported red squirrels present whereas grey squirrels were only recorded in 216.

Other Work

Population studies at Adhurst near Petersfield, Hampshire, and at the Straits Enclosure in Alice Holt Forest, also in Hampshire, were continued.

New types of traps were tested. The Young cagetrap, developed in the New Forest, gave promising results, and it can be produced at low cost, around 10/- complete.

A Grey Squirrel Exhibit has again been displayed at the main Agricultural Shows, and Mr. Courtier has arranged demonstrations of trapping methods to the staffs of various Conservancies of the Forestry Commission and to several Pest Officers of the Ministry of Agriculture. A large number of outside enquiries have been dealt with on matters relating to both red and grey squirrels.

Table 16 *Classification of Squirrel Damage by Species of Tree and Part of Tree Attacked*

Tree Species	No. of areas in which tree species is present	No. of areas in which tree species attacked		Percentage of areas with attacks		Parts of tree usually attacked
		1954	1955	1954	1955	
Sycamore	72	50	37	70	51	Crowns, less often, butts
Beech	96	44	41	46	43	Butts, main stem, roots
Oak	87	18	11	21	14	Upper stem, branches
Birch	60	9	7	15	12	Upper main stem
Ash	68	7	11	10	16	Upper main stem
Sweet Chestnut	47	4	2	8.5	4	Upper branches and stem
Japanese larch	71	5	3	7	4	Upper half of main stem
Scots pine	83	5	2	6	2	Upper branches and stem
Hornbeam	10	5	3	—	—	Tops
Maple	10	3	0	—	—	Tops
Aspen	18	1	1	—	—	Crown
Poplar	34	1	0	—	—	Tops
Corsican pine						—
Maritime pine	damaged in one area	in 1954				Poles
Gean (*Prunus avium*)						Trees only 8 in. to 18 in. high
Thuja	damaged in one area	in 1955				Branches
Lime						Tops
Robinia....						Stems
Lodgepole pine	damaged in one area	in 1954 and in 1955				The top half

MACHINERY RESEARCH

By R. G. SHAW

A WELCOME TREND over the last twelve months has been the growing interest in forestry shown by the makers of agricultural machinery. An instance is seen in the case of light winches where, following the introduction of our own portable power operated winch two years ago, there is already one such winch on the commercial market and another is about to be submitted for trial. The same influence can be seen in the increasing availability of such features as four-wheel drive on tractors and load-carrying vehicles, also in better wheels, and tyre equipment for negotiating the very severe ground conditions frequently associated with forest operations.

The current situation on the main machinery development projects is set out below.

Nursery Operations

This subject has again provided the principal field of investigation for improvement in productivity. Two seed-sowing machines, developed by two foresters to meet their local requirements, have been tested and the results will be seen during the summer of 1956.

A further two Holland lining-out machines, making three in all, have now been imported from America, and modifications have been made to improve their performance under local conditions. Substantial areas have been lined-out with these machines at Bramshill (Hants) Ferndown (Dorset) and Longtown (Cumberland) during the 1956 transplanting season, and thus more evidence on the quality of the planting will shortly be available.

The weeding of seed beds and transplant beds remains a heavy labour-consuming operation, and this is being tackled by both chemical and mechanical means. This section is concerned mainly with the mechanical approach, and here considerable progress has been made on the machine mentioned in the 1955 *Report* as being designed to weed between multiple rows in transplant beds. The prototype has given encouraging results during extended trials, and two further machines will be in use during the summer of 1956.

Extraction of Forest Produce

One-man power saws are playing an increasing part in United Kingdom forests, partly owing to the improved reliability and reduction in weight of these saws and, partly, because forest workers are becoming more machine-minded.

Portable powered winches were virtually unknown in the forest three years ago, but the value of these machines is now becoming widely appreciated. Our own design of winch was introduced two years ago, and it showed how much could be achieved by two men in a short time with a machine capable of a pull of 1,500 lbs. During the past year the Danarm Falcon winch has come on to the commercial market, giving the same pull for a gross weight on only 77 lb. This Falcon winch possesses the added attraction that it can be converted into a Danarm Fury saw, or vice versa, in a matter of minutes.

Other developments in extraction equipment cover a variety of modifications to sledges, sulkies, etc., mainly designed to meet local conditions.

Vehicles

Four-wheel drive plays an increasing part in extraction wherever long distances have to be covered from the stump to the hard road. For this role the recently introduced four-wheel drive conversion by Roadless Traction Ltd. for the standard Fordson tractor, is a welcome development.

Drainage

The Cuthbertson drainage plough continues to give good service in the cutting of new surface drains, but the subsequent drain maintenance has continued to provide a major problem. The self-propelled machines and drag-line bucket mentioned in the last report have not provided any real solution, and the only answer in sight is to cut out one or more lines of trees at intervals in young plantations to allow the entry of tractor-mounted hydraulic diggers, of which several designs are available.

Clearance of Derelict Woodland

A trial of all the known methods for the clearance of derelict woodland has been taking place throughout the last twelve months, but detailed results are not yet available. Each method has been costed on work done on measured plots and compared with clearance by hand under identical conditions.

Bark Peeling

The Scottish-made Kingslaw bark peeling machine became available during the year and a trial to determine rates of output on various sizes and species of timber was carried out. Good results were obtained and one machine is now on a long-term endurance trial.

Tree Planting Machines

An American Lowther machine has been imported and trials are in progress.

UTILISATION DEVELOPMENT

By E. G. RICHARDS

Hardwood Pulping 861

Following the investigations and discussions on the suitability and availability of home-grown hardwoods for pulping, referred to in the 1955 *Report*, Messrs. Wiggins Teape and Co. Ltd., have decided to erect a hardwood pulpmill at Sudbrook, Monmouthshire.

The rate of drying of hardwood pulpwood when stacked in the forest was investigated in the Forest of Dean during the year; a report on the results obtained is given on page 162. In February a second experiment was laid down, comprising stacks made in the open parts of the Forest as well as under complete forest canopy.

The Thinnings House 833

The behaviour of the timbers in the two-roomed experimental office building at Santon Downham was kept under observation. Inspection panels were cut in the plasterboard lining to facilitate examination of the framing and the back of the exterior cladding panels.

There has been no undue distortion of the timbers except for three exterior cladding boards of Scots pine which have twisted badly; one Corsican pine panel has bowed slightly. The sawdust cement and slabwood backings of the exterior cladding units have remained sound. The framing, roofing and joinery timbers have remained stable and the home-grown oak block floor bonded to a concrete screed has given no trouble. In brief, during its first year in service the building has shown no signs of the excessive twisting and warping which has at times been credited to lumber sawn from small-sized thinnings, and has remained completely weather-proof.

Wood Wool 862

An investigation into the species, sizes and specifications of timber required for the manufacture of wood wool was started during the year.

Extractives from Wood and Bark 866.4

The work on the tannin content of fresh Sitka spruce bark was continued; a further fifteen samples of bark from different parts of the country were analysed by the British Leather Manufacturers' Research Association. The average tannin content of these and the sixteen samples analysed during the previous year was 17.5 per cent, a figure high enough to justify further investigations into the effect of methods of peeling on tannin content and the rate of loss of tannin in bark left lying on the forest floor. Results from these investigations are not complete, but during the year under review an analysis of Sitka spruce and oak bark from the stems of trees poisoned in the spring and stripped in the autumn, showed a considerable fall in the tannin content; similarly oak bark from timber which had been felled for a year had lost the greater part of its original tannin content.

A survey was also made of Norway spruce bark. The average tannin content of the ninety-six samples analysed was only 9.4 per cent, which may limit the use of this species on a commercial scale.

Home-Grown Timber in Materials Handling 834

The investigation into the use of home-grown timber in the box, packing case, stillage and pallet manufacturing industries was continued. During the year 134 firms were visited.

LIBRARY AND DOCUMENTATION

By G. D. KITCHINGMAN

Library 945.14

The number of books in the library on the 31st March, 1956, was 2,681, an increase of 177 during the year. 570 books are on permanent loan to Sectional libraries. Other loans of books numbered 681. Borrowing from outside libraries increased from 205 to 289 books. 62 volumes of periodicals were bound, bringing the total to 1,133.

Information Files

This section of the library shows a steady increase, and is now a valuable collection of typescript reports, reprints, translations and miscellaneous material generally.

Documentation

Progress is steady. The number of cards in the indices is now about 69,000, equivalent to about 23,000 references. Lists of references to literature on special subjects have been supplied to enquirers.

Bibliography of British Forest Literature

Progress continues in this special task. All the forestry journals have been completed and work is now in progress on the agricultural, horticultural and botanical journals, some of which go back to the 18th century.

Translation Section

We are now members of the Translation Exchange Scheme arranged by the Commonwealth Forestry Bureau for the recording and exchange of translations on an international basis.

Lists of our translations are circulated in the Library Quarterly and 76 have now been recorded. Full translations and summaries of the more important articles are listed in this way. In addition, a number of abstracts, part-translations and verbal translations are made for members of the Research Branch, and in connection with the documentation of technical literature from abroad.

Translations from Scandinavian languages, as well as from French and German, are undertaken by members of the Library staff. Translators from outside the Commission are often employed for other languages.

Aslib

Close contact was maintained with the Association of Special Libraries and Information Bureaux, of which the Library is a member.

Collection of Photographs

It is encouraging to record that more use is now being made of the Photographic Collection than ever before. Slides loaned for lecture purposes numbered 5,458 as against 5,081 last year. The photographs in the official collection are also in great demand, especially for Forestry Exhibits, by students requiring illustrations for their theses, by staff of the Commission for illustrating lectures and publications, and also by the general public.

During the year the number of colour slides and monochrome prints increased from 2,606 to 3,163 and from 11,833 to 12,365 respectively. In the twelve-month period a total of 488 orders were received by the section, amounting to 9,585 separate items of printing, developing, or mounting. A certain amount of cinematograph work was done, mainly on a film of the life history of the pine looper moth, and on short records of machinery trials. Film distribution amounted to 105 items during the year.

Library Quarterly

Two numbers were issued during the year. A new feature—a section devoted to important articles from periodicals—has been appreciated and, if time and staff permit, will be continued. A list of forestry books published in Great Britain before 1800 was included in the January number.

PART II

Research undertaken for the Forestry Commission by Workers attached to Universities and other Institutions

NUTRITION PROBLEMS IN FOREST NURSERIES*

By BLANCHE BENZIAN and R. G. WARREN
Rothamsted Experimental Station, Harpenden, Herts.

Needle Tip-burn

232.322

In the Rothamsted Report for 1953 mention was made of a symptom called "needle tip-burn" which had been observed for a number of seasons in Sitka spruce seedlings and transplants at Sugar Hill Nursery, Wareham Forest, Dorset. This nursery is on a very acid sandy soil which had previously carried *Calluna* and scrub pine. The symptoms tend to appear after a hot spell in midsummer. They occur on many of the fertilizer plots, but have only rarely been observed on plots which have received a dressing of a standardized compost made from bracken and hopwaste.

During the 1955 season foliar applications of several micro-nutrients, i.e. copper, zinc, manganese and molybdenum, were tested on Sitka spruce seedlings at Sugar Hill Nursery. On plots which had received a foliar spray of copper sulphate applied in June at the rate per square yard of 0.16 g. Cu in 300 ml. water, tip-burn symptoms were completely absent until the middle of August and developed only slightly during the remainder of the season. Plots without copper sulphate showed tip-burn from the beginning of August, the symptoms increasing in severity throughout the summer and autumn. At the end of the season the mean height of the "no copper" plots was 1.9 and of the "copper" plots 2.8 inches. None of the other micro-nutrients appears to have reduced the symptoms.

In experiments on both Sitka seedlings and transplants raised in 1955, testing fertilizer and compost made from bracken and hopwaste, tip-burn developed on fertilizer-treated plots but was absent from compost plots. Beds which had received both compost and fertilizer together showed slight symptoms. The hopwaste used in the making of compost is known to contain several hundred parts per million of copper (dry matter basis), and a compost dressing of ten lb. per square yard generally prevents the appearance of the symptoms.

Methods of Formalin Applications

Although formalin applied as a drench (formalin diluted with water approx. 1 in 20) has proved consistently good in experiments extending over many seasons and soils, it has not been found easy to use the method on a large scale

* Also reproduced in the Rothamsted Annual Report for 1955.

in Conservancy nurseries because of the difficulty of applying large volumes of liquid by machine and the lack of a sufficient water supply in some of the nurseries. In 1955, neat formalin was placed in drills approximately 2 inches deep and $1\frac{1}{2}$ inches wide with 9 inches between the drills. The treatment was applied either in December or in February at rates of 25 and 50 ml. per yard of drill. The seedlings above the formalin drills compared favourably with those on plots raised with formalin drench. As there was little sideways-spread of the effect of neat formalin, the test will be repeated in 1956 with closer spacing of the drills.

Root examination

Mr. D. M. Griffin, working under Dr. Garrett, Director of the Sub-Department of Mycology, Botany School, Cambridge, has continued mycological examinations of plants from many of the experiments. The summary of the main result of his investigation is the conclusion that stunting in coniferous seedlings is not due to root-rot. Mr. J. B. Goodey, Nematology Department, has continued his study of nematodes in experiments at Ringwood Nursery.

EFFECTS OF TREE GROWTH ON SOIL PROFILE DEVELOPMENT

By Dr. T. W. WRIGHT

Macaulay Institute for Soil Research, Aberdeen

Corsican Pine Nutrition 181.343: 114.33

The study of the seasonal fluctuations in nutrient content of the foliage of young Corsican pine at Culbin Forest under different thinning grades, and their relationship to soil moisture, has been completed (c.f. *J. Soil Sci.*, Vol. 8(1), 1957). The investigation has shown that:

(1) Foliage nutrient fluctuations follow the trends found on other more normal soils at the beginning of the growing season, but show marked abnormalities later in the year.

(2) These abnormalities can be correlated with changes in soil moisture storage, calculated from meteorological data by Penman's formula.

(3) Heavy thinning results in improved soil moisture conditions, and on the poorer sites delays for several weeks the decrease in foliar nitrogen, potassium, and magnesium, which occurs when available moisture in the rooting zone is reduced by spring drought.

The assessment of the response of young Corsican pine to phosphate manuring has been continued for a second year. No response in height growth has been observed, and the slight increase in the calcium content of the foliage at the end of the first growing season has not been maintained. This may be due in part to the abnormally dry summer of 1955, which reduced height increment in all the plots by about 50 per cent compared with 1953 and 1954.

Since the work in the thinning plots has shown that the nitrogen, potassium, and magnesium contents of the pine needles are most sensitive to changes in site conditions, and since the foliage nitrogen content of the trees at Culbin is known to be considerably lower than that of Corsican pine growing on more normal soils in the same area, a further experiment has been laid down on the sand dunes to test the effects of fertilizer applications of these elements on tree growth. The treatments are sulphate of ammonia (5 cwt. per acre), potassium chloride (2½ cwt. per acre), and magnesium sulphate (2½ cwt. per acre) in a factorial design, and assessment will again be by height growth measurement and foliar analysis.

Tree Growth on Deep Peat

The work at the Lon Mor, Inchnacardoch Forest, has been continued by Mr. W. O. Binns, who joined the Institute in August 1955. First results of the study of the physical and chemical properties of unplanted peat, and of peat bearing trees with and without the addition of phosphatic fertilizers, indicate considerable, and possibly irreversible, drying out of the peat under the most vigorous trees, resulting in appreciable vertical shrinkage and the formation of surface fissures. The phosphate content of the peat is being divided into organic and inorganic fractions.

Soil Studies in Thinning Plots

The monthly litter collections from the Norway spruce thinning plots at Bowmont Forest, Roxburghshire, are being continued for a full year. The accumulation of organic matter under the lighter thinning grades has resulted in significant changes in some physical and chemical properties of the surface soil, notably in the phosphate and calcium content, and in the water-stable micro-aggregates below .02 millimetres.

INVESTIGATIONS ON THE CHEMICAL NATURE OF THE PROTEIN PRECIPITATING CONSTITUENTS OF LEAVES

By Dr. H. Raudnitz

Imperial Forestry Institute, Oxford

114.351

Based on an observation made by Dr. Handley—cf. *Mull and Mor Formation in Relation to Forest Soils*, Forestry Commission Bulletin No. 23—that leaves of certain species contain protein precipitating materials which seem to affect the readiness with which the plant litter is attacked by litter destroying fungi, a chemical investigation into the nature of these leaf constituents has been undertaken.

First a reliable method was worked out by which the whole complex of water soluble, protein precipitating substances present in e.g. rhododendron leaves could be isolated. Owing to the sensitivity of these substances to heat, this and successive operations had to be carried out at room temperature. By extractions with solvents of increasing polarity, a further separation of these compounds was achieved. At present, the main effort is directed towards accumulating larger quantities of these materials, i.e. increasing the available quantities from a milligram scale to a gram scale, and obtaining them in a chemically pure condition for further examination.

So far, the isolation of a glycoside has been achieved which, on hydrolysis, afforded a yellow aglucone and rhamnose and arabinose as the sugar components. Further, the presence of a leuco-anthocyanine was established which could readily be converted into an anthocyanine and anthocyanidin respectively, the nature of which seems different from those encountered normally in leaf extracts.

Simultaneously, an investigation of the naturally occurring pigments in the flower petals of rhododendrons is being carried out which might prove helpful in the identification of the above-mentioned artefact. From another fraction, a viscous liquid, volatile under high vacuum, and a crystalline acid were isolated, and it is hoped that these components will be identified in the near future.

RESEARCHES IN SOIL MYCOLOGY

By Dr. IDA LEVISOHN

Bedford College, University of London

Behaviour of Mycorrhizal and Non-mycorrhizal Stock after Planting in a Certain Soil 181.351

Comparison of the performance of mycorrhizal nursery stock with non-mycorrhizal stock of the same species is of particular interest in cases where planting is carried out on poor sandy soils such as the heathland soil at Wareham, Dorset. From experience gained in connection with the researches conducted by the Nursery Nutrition Committee, it appears a very difficult task to study this fundamental problem in the framework of field experiments.

In order to examine each individual seedling just before planting, and to ensure the presence or absence of mycorrhizal infection, controlled experiments were carried out in the grounds of Bedford College, London. Sitka spruce, the main test plant in the Nursery Nutrition Committee researches, is particularly unsuitable material for investigations relating to root infection; consequently Scots pine was used for these experiments. The pines were grown in pot-cultures with soil from an area at Wareham, afforested in 1938, which is extremely low in nutrients and micro-biological activity. A set of mycorrhizal plants was raised in this soil, treated with a bracken-heather compost. Non-mycorrhizal seedlings were obtained by sowing in the Wareham soil sterilized, to which the same compost had been added.

After two years of growth, the two sets of plants, which exhibited similar height and vigour, were carefully examined as regards root infection. The seedlings grown in the composted soil not sterilized, showed a rich development of normal mycorrhizas formed by the fungus *Boletus bovinus*; those raised in the composted soil which had been sterilized were free from any infection.

In the autumn, the plants were transferred to two separate pits filled with soil transported from the same Wareham area. (The pits, provided with an efficient drainage system, had the following measurements: length 4 ft. 6 in., width 3 ft., depth 18 in.) The mycorrhizal trees made excellent growth, producing long needles of good colour. The (originally) non-mycorrhizal plants exhibited poor growth and a chlorotic foliage.

Root examination carried out during two growing seasons showed that the mycorrhizal trees continued to produce mycorrhizas of *Boletus bovinus*. The non-mycorrhizal plants raised in the sterilized soil were found to develop a small number of subnormal infections, the typical 'messy' type of association known to be formed by *B. bovinus* in untreated Wareham soil.

Further investigations of the kind described above are planned for pit and field experiments in order to ascertain how far the behaviour of tree species after planting out can be forecast from their root infection.

Pits with soil from Wareham were also used for testing the performance of pine seedlings raised in a more fertile heathland soil from Surrey. These plants were supplied with abundant normal mycorrhizas formed by unidentified mycelia, and an additional very small proportion of associations of a parasitic fungus (*Rhizoctonia sylvestris*). When planted out in the pits, these trees went into severe check. The infections of *R. sylvestris*, innocuous to the development of the trees under the soil conditions in Surrey, became deleterious when brought into the different environment provided by the Wareham soil in the pit.

The result of this experiment confirms earlier observations which point to the danger of an indiscriminate use of 'mycorrhizal" trees for planting purposes. Failure in forest plantings might be avoided by preliminary tests in pot-cultures or pits.

Effects of Boletus scaber on the Growth of Birch and other Tree Species

Investigations continue as to the effect produced by *Boletus scaber* on the growth and vigour of tree seedlings. Experiments carried out during 1953 and 1954 (*Rep. For. Res. 1954, 1955*) were repeated and extended, and the earlier results confirmed for all species tested.

After the first growing season, the average shoot length of birch grown in Wareham soil, with one-third of the usual amount of compost added, was as follows:

(a) Control series, not inoculated with *B. scaber* (35 plants) 3.61 in.

(b) Series inoculated with *B. scaber* (36 plants) 4.85 in.

Earlier experiments with Norway spruce and *Robinia pseudacacia* showed a definite benefit following inoculation. Cultures of *R. pseudacacia* provided with mycelium of *B. scaber* were equal in height to series which had received nodule inoculation. The latter were, however, much superior in colour of foliage which was dark-green, while chlorosis developed in the plants without this inoculation.

Additional experiments demonstrated stimulation of Lawson cypress seedlings as early as four months from inoculation with *B. scaber*.

Trials in a Yorkshire Moorland Soil

In the untreated soil from Wykeham Moor, the fungus-inoculation did not cause improvement of birch. There was, however, a definitely beneficial effect noticeable on the pot-culture seedlings growing in sterilized soil into which the mycelium of *B. scaber* had been introduced. Here, survival and shoot length was significantly superior as compared with the uninoculated cultures in sterilized soil. Root examination showed that, at the time when stimulation was recorded, mycorrhizal contact had not yet been established, i.e. that, at least at this stage of seedling development, the beneficial effect on the plant was due to the rhizosphere activity of the mycelium. The one-year seedlings in the unsterilized series were also found to be non-infected.

When compared with the effect produced in the sterilized soil, the failure of the fungal inoculum to stimulate the plants in the untreated soil strongly points to the fact that *B. scaber* is already present in the latter soil. This conclusion is in agreement with the observations made by the team of research workers at the Forestry School, Oxford, that *B. scaber* is a dominant mycorrhizal mycelium in most of the Yorkshire moorland soils.

Growth on Birch Litter

Influence of *B. scaber* on birch development was also observed in experimental sets originally devised to study the activity of this fungus in various types of litter.

Small flower pots, containing birch litter mixed with broken crocks to induce better aeration, were inoculated with fragments of sporophores as well as with pure-culture mycelium of *B. scaber*. In some of the pots, which were kept in the open, self-sown birch (the seed contained in the litter) developed. In their second year of growth the seedlings, three to four inches in height, were observed to possess an extensive fibrous root system just beginning to form mycorrhizal associations.

Further experiments in which litter is inoculated with mycorrhizal mycelia are in progress.

Mycorrhizal Infection in Cuttings

Since researches have demonstrated that the rhizosphere activity of certain mycorrhizal mycelia can produce stimulation of tree seedlings, it would be of interest to ascertain whether such influence also exists in the case of cuttings.

Samples of a variety of species including trees which "take" easily and such which root with difficulty, were kindly supplied by Alice Holt Research Station, Kennington Nursery, Long Ashton Research Station, Chelsea Physic Garden, and Kew Gardens. An additional number of cuttings came from casual sources. Details of their history, e.g. kind of rooting medium and soil for lining out, varied considerably. Included in the material studied were samples of willow species from field trials at Sugar Hill (Wareham), Bagley Wood, Kennington Old Nursery, and from experimental pot-cultures with soil transported from these three localities. The following trees were examined for root infection: species of *Sequoia, Metasequoia, Cryptomeria, Sciadopitys, Cupressus, Abies, Picea, Tsuga, Pinus, Populus, Salix, Platanus, Eucalyptus.*

Endotrophic Species. Among the young cuttings examined, some samples of all species were recorded as mycorrhizal, namely species of *Sequoia, Metasequoia, Cryptomeria, Sciadopitys, Cupressus, Platanus.* It appears that presence or absence of mycorrhizal association and degree of infection mainly depends on the nature of the soil in which the cuttings are grown.

Ectotrophic Species. As regards the ectotrophic species examined, namely species of *Abies, Picea, Tsuga, Pinus*, only a two-year-old cutting of *Pinus radiata* (from Alice Holt) exhibited mycorrhizal infection. This was of a subnormal type. The general difficulty in rooting of a number of these ectotrophic species, bound up with factors disturbing the normal transport of food supply to the rooting base, may well be regarded as also responsible for the failure to establish mycorrhizal contact.

The behaviour of a three-year-old cutting of *Pinus sylvestris* from Kennington is of special interest insofar as the root system, which was rather poor in relation to the well-developed shoot, showed quite a number of forked short roots. However, no trace of infection was observed. From the history of this cutting it appeared unlikely that a mycorrhiza-former for the species was present in the soil in which it had been growing; therefore another factor—so far unknown—must be held responsible for inducing the forking.

Populus, Salix and Eucalyptus. These genera, generally propagated by cuttings, cannot be grouped with ease in either the ectotrophic or the endotrophic class, since examination of seedlings and mature trees has shown that they possess a certain 'mycorrhizal elasticity'. Although ectotrophic associations are formed under a wide range of conditions, endotrophic infections have been observed to occur in all three genera. From results of pot-culture experiments, and from field observations, it would appear that the type of infection—ectotrophic or endotrophic—is determined by environmental factors, and that taxonomic relationships are not involved.

Cuttings of a number of species belonging to the genera *Populus*, *Salix*, and *Eucalyptus* have all been found to be notably poor in mycorrhizal infection. No mycorrhizal associations were recorded in one-year-old cuttings in any of the three species of *Populus*, fifteen species of *Salix*, and eighteen species of *Eucalyptus* examined in the course of this investigation. Two to three-year-old cuttings have shown very casual infection.

Considering that the young cuttings studied belong to genera which are fast-growers par excellence in conditions where they grow well, one may be inclined to associate their lack in mycorrhizal infection with a possible deficit in the sugar content of the roots. According to Björkman's carbohydrate theory, the deficiency in sugar (which may be used up as building material in the development of the very fast growing shoots) would discourage mycorrhiza-formation. However, the connection between total absence or conspicuous scarcity of mycorrhizal associations in these fast growing cuttings and a hypothetical carbohydrate deficit in the roots, is merely a surmise; chemical analysis of the root-cell contents is required in order to elucidate the point raised here.

FUNGAL DAMAGE TO ROOTS OF SITKA SPRUCE SEEDLINGS IN FOREST NURSERIES

By D. M. GRIFFIN

Botany School, University of Cambridge

443.2

SINCE THE 1955 *Report* was made, a large-scale detailed examination has been made of the seedling root systems of Sitka spruce, and of some other coniferous species, raised in a number of forest nurseries in which experiments on partial sterilization of the soil were undertaken for the Nursery Nutrition Sub-committee.

In the assessment of root damage in any plot, a random sample of twenty seedlings is taken; in the examination of each seedling, the number of dead root tips out of one sample of twenty (working back from the tip of the tap root) is recorded, together with the status of the tap root (alive or dead). The Root Damage Score for each plot examined is then presented as the mean percentage of dead root tips, together with the mean percentage of dead tap roots. This method works well for Sitka spruce, in which the root system tends to be shallow and well branched, and has been found workable by other investigators. As Sitka spruce has been the chief test species in these experiments on partial sterilization of the soil, there has been no need to modify this method of root damage assessment, but it is worth noting that sampling and damage assessment are more difficult with a species such as *Pinus halepensis*, in which the seedling root system is deeper but less freely branched. The Root Damage Score does not, without laborious supplementary examination in the laboratory, distinguish between root tips killed by fungal pathogens and those killed by other causes, e.g. waterlogging, drought, etc. It therefore provides an estimate of the *maximum* damage that could have been caused by fungi on any plot thus examined.

The main conclusion to be derived from the examination of Sitka spruce and other coniferous seedlings in 1954 and 1955 is that damage by fungal pathogens is clearly inadequate to account, either wholly or chiefly, for the poor growth of seedlings in soil-sick nurseries. The much improved growth following upon soil treatment with partial sterilizing agents must therefore be attributed to some factor other than control of root pathogens, even though the latter effect may contribute something to the overall improvement in growth on treated soils. It thus seems likely that changes in the amount and nature of available soil nitrogen after partial sterilization may be responsible for a greater part of the partial sterilization effect in promoting growth, than has heretofore been supposed.

Although this survey has tended to minimise the part played by fungal pathogens as a cause of soil sickness in forest nurseries, it should be noted that sporadic occurrences of damping-off have been found fairly widespread in all nurseries, excepting those with a very acid soil or those that are newly established. The chief pathogens encountered in this survey have been species of *Pythium*, and especially *P. ultimum* and *P. debaryanum*.

FOMES ANNOSUS IN EAST ANGLIA

By Dr. J. RISHBETH

Botany School, University of Cambridge

443.3

INVESTIGATION into various aspects of this problem has recently been reopened. The current loss for all pine thinnings, calculated from the proportion by volume of trees killed by *Fomes annosus*, is of the order of 4 per cent. Over considerable areas on acid soils the loss is commonly smaller than this, but on alkaline soils it is often much greater, sometimes exceeding 30 per cent. A few severe outbreaks have developed recently: thus at one site Scots pine suffered less than 2 per cent loss through *F. annosus* at the second thinning in 1951, but nearly 30 per cent at the third thinning in 1956. Some plantations affected earlier have developed considerable resistance to the parasite, and disease gaps are virtually stable, whereas in others, particularly at sites where the chalk is near the surface, trees are being killed as rapidly as ever. Where pine is underplanted with beech, some of the latter often become infected when the pine is thinned, but so far damage does not appear to be serious. That caution is required even with hardwoods is suggested by the fact that in one area *F. annosus* has killed fifty-year-old birch and beech in plantations where conifer stumps became infected after felling in 1944.

Counts have been made of trees killed by *F. annosus* in two compartments where various stump treatments were carried out in 1947-49. The results show that in plots where stumps were painted or creosoted immediately after felling, far fewer trees are dying than in plots where no treatment was given. Where natural stump infection with *F. annosus* was high, stump treatment has reduced killing by about 90 per cent. From these and other experiments it is clear that with first rotation pines on sites favouring development of the disease the incidence of killing is chiefly determined by the proportion of stumps infected by the parasite at the first thinning or at the time of rack-cutting. For this reason a plantation or group of comparable plantations thinned in a similar manner at various times of the year tends to suffer a varied intensity of attack. It is also evident that small trees cut out for any reason prior to thinning, as during brashing, may initiate infection. With small unthrifty pines infection occasionally occurs through brashing wounds, but this type of infection seldom becomes established in normally healthy pines.

In East Anglia, treatment of first-thinning stumps with creosote was started in 1952 at selected sites, and in 1954 the treatment was extended to second-thinning stumps and to plantations on a wide range of sites. The effectiveness of this method of protection is being tested by leaving small strips of stumps uncreosoted during thinning at various times of the year. Experiments are in progress to investigate the extent to which effectiveness depends upon the amount and the timing of creosote application, and various other substances are being tested as possible protectants.

To discover whether the modes of infection by *F. annosus*, prevalent in East Anglia, occur elsewhere in Britain, and to obtain a more representative picture of the pathogen's activities, a tour of various forests was undertaken with Mr. J. D. Low in the summer of 1955. Although killing of pines seldom occurred on the scale found in East Anglia, a notable exception being parts of Tentsmuir Forest in Fife, attacks were found to originate in the same way. Similarly, the more widespread butt rot of larch and spruce, caused predominantly by *F. annosus*, was common and sometimes severe on sites formerly bearing conifers and in a few instances early stages were detected on non-woodland sites where thinning had taken place. In no instance was it necessary to postulate a mode of infection other than by root contact with infected stumps, although in view of the observation about brashing wounds made above one can expect occasionally to encounter stem infections in conifers other than pines. It is clear that *F. annosus* is already becoming established in many new plantations, the sourse of infection (through air-borne spores) doubtless being former woodland sites nearby. Since stump treatment may come to be accepted as an economically justifiable means of protection against butt rot, at least in some circumstances, it is planned to set up a few experiments in Welsh and Scottish localities where *F. annosus* is already present.

Mr. D. S. Meredith, of Cambridge University, has recently begun observations at Thetford Chase on the ecology of fungi inhabiting stumps.

THE RELATIONSHIP BETWEEN LARCH CANKER, TRICHOSCYPHELLA AND FROST

By Dr. J. G. MANNERS
Department of Botany, Southampton University

443.3

Work has continued along the lines suggested by the results of investigations noted in previous *Reports*.

The Inter-relationships between Trichoscyphella willkommii and Frost

It was shown in an earlier phase of this work that frost damage and *T. willkommii* could each cause histologically similar cankers, and a full account of such cankers is being prepared for publication. Experiments were therefore started in 1955 with a view to investigating directly the inter-relationships between frost damage and fungal attack; the effect of wetness of the bark on frost damage was also studied in the same experiments. Potted trees of each of three provenances of European larch were locally frost damaged by a cold air stream. One set was then exposed to cankers bearing fungus fruit bodies, one set sprayed with a spore suspension, and one set left as a control. A further set was frozen while wet and then sprayed with a spore suspension.

The effect of inoculation with the fungus is not yet apparent, there being a delay of one to two years between inoculation and the appearance of fungus-induced cankers; but the effects of the freezing treatment have been recorded. Of forty-eight trees frozen, twelve developed cankers within nine months and eight more developed frost cracks, while in four a lateral shoot was killed. Eight trees were unaffected, while sixteen were ringed. 75 per cent of the trees frozen when wet were ringed, while only 20 per cent of those frozen dry suffered to this extent. Although no fungus fruit bodies or mycelium have appeared yet, it may be significant that, ringed trees excluded, the proportion of cankered trees was higher in inoculated than in uninoculated sets. The trees of Alpine provenance were more severely frost-damaged than those of Polish or Sudeten origin: this may have been due partly to their being smaller trees.

Further observations will be made on these trees during the coming year and a second, similar experiment, including Japanese larch, as well as European larch, has been commenced.

Taxonomic Studies

Studies on the taxonomy of *Trichoscyphella* and related genera are still in progress, a number of new problems having recently emerged. A number of points have been resolved: an examination of the type specimens have shown that *Peziza comitessae* Cke is a synonym of *P. calycina* sensu Cooke (which is *T. hahniana* (Seaver) Manners). The fungus outwardly resembling *T. hahniana*, which is associated with cankers on Scots pine in the New Forest and elsewhere, is distinct from *T. resinaria*, a fungus of *Picea* bark, though closely resembling it. The valid name of this fungus is *Lachnellula schumannii* Rehm. (the previous British record was under the name *Trichoscypha vuillemini* Boud). The difficult "*calyciformis*" group is being studied in detail, modifications have been made to the key to species in the light of further experience, and the collection of material for the publication of a revision of the group continues.

STUDIES ON MERIA LARICIS NEEDLE-CAST DISEASE OF LARCH

By P. BIGGS

Department of Botany, Southampton University

443.2

NEEDLE-CAST of larch has been known in this country for many years as a serious disease of nursery trees. Until 1954, however, infection had only been recorded on European and Western larches, but in the summer and autumn of that year the disease was observed on both hybrid and Japanese larches (Batko 1955), and an investigation of the disease was undertaken at the request of Mr. T. R. Peace, the Forest Pathologist.

Isolation and Culture of the Fungus

The fungus *Meria laricis* Vuill. has been isolated from diseased material sent by Forestry Commission nurseries throughout the country, and the fungus maintained in culture on Doxyeast agar.

Peace and Holmes (1933) obtained two distinct strains of the fungus, the 'a' strain and the 'b' strain, differing in cultural characteristics. From recent isolations, however, eight distinct strains of *Meria* have been recognised; four in the 'a' group and four in the 'b' group. It is not yet certain whether these strains are genotypes or whether even they are in reality aggregates.

Peace and Holmes (1933) indicated that the 'b' strain was most common in isolations from nature, but most recent isolations belong to the 'a' group of strains as defined in the present investigation. But, while the 'a' strain recognized here corresponds to the 'a' strain of Peace and Holmes in some cultural characteristics, it does not do so in all, indicating that these two strains may not be identical: hence caution must be exercised in drawing conclusions concerning changes in the relative abundance of the 'a' and 'b' strain groups. Infections from nature are actually mixtures of strains, as two or three strains can be isolated by the single spore method from a single diseased plant.

Several experiments on the effect of environmental factors on the growth of the fungus in culture are being undertaken in an attempt to determine whether isolates of the fungus from the three tree types, European, hybrid and Japanese larch, differ in any respect, as the 'a' and 'b' strain groups occur indiscriminately on all three.

Inoculation Experiments

In order to provide trees for experiments at all seasons of the year, batches of European, hybrid and Japanese larches, supplied by the Forestry Commission, were placed in a greenhouse light chamber with a sixteen-hour day. Trees placed in the chamber, after being kept in an unheated greenhouse subsequent to needle-fall, broke dormancy in about three weeks and were ready for experimentation after six weeks. So far, only preliminary experiments have been carried out with the object of testing inoculation methods and obtaining stocks of inoculum. Infection has been obtained by the two inoculation methods used, but was poor, possibly due to the presence of conditions adverse to spore germination. Further experiments are necessary before undertaking the cross-inoculation work.

Proposed Future Work

(a) Cross-inoculation experiments are under preparation to test the reaction of the European, hybrid and Japanese larches to isolates of the various strains from each of these three tree types.

(b) A field experiment is planned in order to obtain information regarding the spread of the pathogen.

(c) The possible occurrence of physiologic races of *Meria* which differ in their pathogenicity towards European, hybrid and Japanese larches will be investigated, together with their relationship to the morphological strains already described.

(d) The isolation of *Meria* from infected material sent from nurseries throughout the country will be undertaken in order to obtain information concerning distribution of the various strains.

REFERENCES

Batko, S. (1955). *Meria laricis* on Japanese and hybrid larch in Britain. *Trans. Brit. Mycol. Soc.* **39**(1), 13-16.

Peace, T. R. and Holmes, C. H. (1933). *Meria laricis*, the leaf-cast disease of larch. *Oxford Forestry Memoirs* No. 15, 28 pp.

STUDIES ON KEITHIA THUJINA

By R. G. PAWSEY
Department of Botany, Nottingham University

443.2

TWO MAJOR LINES of work have been followed, first an attempt to obtain *Keithia* in artificial culture and second the elucidation of the life history in nature.

In spite of the use of a wide range of media, with a variety of physical characters, all cultural experiments have so far proved abortive, but are still being developed. Germination of the ascospores has regularly been obtained on agar and on sterile *Thuja* material, but there has been no development beyond the germ tube stage. The optimum temperature range for germination has been found to be from 12 to 15° C. (54°-59° F.).

Two experimental nurseries have been planted, one in the Nottingham University grounds, and the other in the Blidworth beat of Sherwood Forest. Life-cycle work has been based on plants in these nurseries. So far two over-wintering mechanisms have been found, the most important of these being the surface inoculum of ascospores on the plants, which apparently remain viable until the following spring, when infection takes place. The conditions associated with this dormancy and then renewed activity are being investigated. The second mechanism is the production in the autumn of incipient apothecia, which overwinter in the paraphysis stage, on infected leaves retained on the plant, until early spring, when activity is resumed and the apothecia develop to maturity. Apparently, in Nottingham this year, this alternative has been of little importance in producing the heavy infection in the spring 1956. No imperfect stage of *Keithia* has been observed.

Experimental ascospore inoculation and infection has been carried out and the critical factors controlling this are being assessed. Inoculation with infected tissue has proved unsuccessful.

Preliminary work has been started on the factors associated with discharge of ascospores. This shows that discharge occurs over a wide range of temperature and a limited range of humidity conditions. In stable conditions discharge is apparently continuous, in contrast with the puffing type of discharge of a large number of Discomycetes.

Work on the development of the parasite in the host tissue is continuously in progress.

SOIL FAUNAL INVESTIGATIONS

By Dr. P. W. MURPHY
Rothamsted Experimental Station, Harpenden, Herts.

114.67

IN SEPTEMBER, 1955, the writer returned to Rothamsted following a period spent at the Zoological Institute of the University of Vienna. Work has continued on an investigation of the fauna of rendzina soils, a programme commenced in Austria, and further progress has been made with laboratory studies of soil-inhabiting mites. A paper describing routine methods used in sample preparation and handling of the extracted fauna has been prepared for publication. This paper is complementary to one dealing with the extraction process, now in the press, details of which were given in the *Report* for 1955.

A paper concerned with some investigations of the biology and food habits of soil-inhabiting Acarina species is at present being prepared for publication. The objects of these studies, which have extended over a number of years, concern culture methods, food habits, quantitative data of the amount of food ingested, and food preferences of litter-feeding species. The latter was an attempt to find if any relationship existed between the palatability of the litter species and its reputed rate of decomposition on the forest floor. Some of the results of these investigations have been referred to in previous reports.

The Oribatoidea have proved difficult culture subjects, and most investigators report high mortality rates especially amongst the immature stages, a finding which is fully corroborated by the writer's experiences. Unsuitable methods have much to do with this situation, and a new culture technique recently devised may overcome some of these difficulties. The species studied and their principal reactions to culture conditions are outlined in Table 17; of these *Steganacarus magnus* (Nic.), *Hermannia gibba* (Koch) and *Tectocepheus velatus* (Mich.) were the principal species used in the investigation of food habits.

The principal food sources were leaf litter and fungi. With the former, species had very different reactions, some feeding voraciously whilst others showed little apparent signs of feeding. The extreme condition was demonstrated by *T. velatus*, which although reproducing fairly readily, was not observed to feed with certainty, and there were no obvious signs of excrement. The most successful culture subjects were *S. magnus* and *Nothrus silvestris* Nic. In food-preference experiments the former showed a definite preference for broadleaf as opposed to conifer litter and ash to birch.

Oribatid Species Cultured and their Reactions to Culture Conditions

Table 17

Species	Feeding observed	Excrement	Eggs	Larvae	Nymphs	Maximum time adults observed alive in culture (days)
Steganacarus magnus (Nic.)	+	+	+	+	+	650
Hermannia gibba (Koch)	+	+	+	+	+	318
Tectocepheus velatus (Mich.)	?	?	+	+	+	318
Nothrus silvestris Nic.	+	+	+	+	+	255
Carabodes minusculus Berl.	+	+	—	—	—	269
Oribella lanceolata (Mich.)	?	?	—	—	+	74
Oppia spp.	?	+	—	+	—	—

Table 18 gives the areas of ash and birch leaf-litter discs consumed by a culture of 78 mites maintained at room temperature for a period of 96 days. It was not possible to determine the areas of conifer needles ingested because although some feeding took place within the needles (especially larvae) there were very few complete perforations. A culture of *N. silvestris* is of particular interest from the point of view of litter preference. Adults of this species were provided with *Calluna vulgaris* and Sitka spruce litters obtained from heathland (Allerston Forest area, north-east Yorkshire) and forest plantings nearby. There was very little difference in preference, and quite large quantities of *Calluna* were ingested.

This result is rather unexpected in view of the nature of *Calluna* litter, and the length of time it remains apparently little altered under natural conditions.

For the cultures with fungi as food source, the three oribatid species already mentioned were provided with *Clitocybe nebularis* Quél. and *Phoma radicis-callunae* Ternetz. The former is a common woodland species and is considered to be a saprophyte on litter, and the latter forms an endotrophic, mycorrhizal association with *Calluna vulgaris*. The results of these experiments were somewhat inconclusive, partly due to the culturing technique proving unsuitable, and no clear evidence was obtained that these mites could exist on a purely fungal diet.

Estimates were made of excrement-pellet production by *S. magnus* cultures provided with tree litters (ash and Scots pine), the mean per mite per day (room temperature) being 0.75 and 0.61 pellets respectively; peak rates in both cultures were about two per mite per day. Certain species produced characteristically shaped pellets, and it may be possible to identify, at least to a certain extent, the sources of excrement found in the soil. The most characteristic shape was a cylindrical pellet with rounded ends, and smooth outer surface (*H. gibba* and *Carabodes minusculus* Berl.). *S. magnus* tended to produce a round pellet with small pieces of detritus clearly visible on the outer surface, giving it a roughened appearance. This feature might suggest that the pellet's passage through the gut is relatively rapid. The pellets of *H. gibba* were fairly constant in size, and had an average diameter of 110 microns and 160 microns long. *S. magnus* pellets had an average diameter of 135 microns, but were much more variable in size. However, this might be expected as there is a considerable size range amongst the adults of this species.

Consumption of Leaf Litter by Mites

Table 18

Litter	Area square millimetres	Area ingested, complete perforations, square millimetres	Percentage ingested	Area partially ingested, square millimetres
Ash disc A	23.8	11.0	46.3	—
Ash disc B	23.8	12.5	52.8	—
Birch disc A	21.7	3.6	16.6	1.2
Birch disc B	21.7	3.9	17.9	0.4

Eggs, larvae and nymphs were found at various stages during these investigations (Table 17), but the complete development of individuals from egg to adult was not observed, although it might have occurred in a few instances. Larvae of *S. magnus* were very difficult to observe as they often remained within the interior of conifer needles. Of the main culture species, *T. velatus* produced most larvae and nymphs, which was somewhat surprising as in other respects it appeared to be the least successful culture subject. Evidence from these culture experiments lends support to field observations that the development of some oribatid species is extremely slow, and that under natural conditions the life cycle may occupy at least one year.

Adults of some species lived a very long time in culture (Table 17), the record length being a culture of *S. magnus* where individuals remained alive for 1¾ years. This culture was maintained at room temperature for 540 of the 650 days. Species living for 300-400 days included *H. gibba* and *T. velatus*. The other species were cultured to a lesser extent, and on that account are not directly comparable with those already mentioned.

There is increasing evidence of a close linkage between fungi and soil fauna in decomposition processes. The large amounts of apparently unaltered litter in the excrement of litter-feeding species is a pointer to the idea that mites ingest large amounts of leaf material in order to obtain the fungi which are present either as symbionts, or invade senescent leaves shortly before or after they reach the ground. It is possible that freshly fallen leaves are not favoured because a conditioning period is necessary during which a symbiotic or weakly parasitic fungus species, no longer inhibited by its erstwhile partner, pervades the whole leaf tissue. There is also evidence of a sequential pattern in organic-matter decomposition with a succession of fauna and flora associated with it, and this implies a considerable degree of specialization amongst the initiators of the process. Present studies are directed to this aspect in order to determine whether there are successional biological phases in litter decomposition, and if so the species associated with each stage.

The writer is indebted to Dr. W. R. C. Handley of the Department of Forestry, University of Oxford, who provided the fungus cultures used in these investigations.

BIOCLIMATIC STUDIES ON THE PINE LOOPER, BUPALUS PINIARIUS L.

DR. N. W. HUSSEY

Department of Agricultural and Forest Zoology, Edinburgh University

145.7:151.1

STUDIES on the effect of temperature and humidity on the development of *Bupalus* were concluded during the year, and as the results will be presented more fully elsewhere only the main conclusions will be summarised here.

(i) Females lived longer than males, but both sexes survived several weeks at low temperatures and retained fertility.

(ii) The minimum temperature for successful oviposition was 52°F., but optimum conditions lay within a temperature range 64 to 73°F., and relative humidities of 79 to 95 per cent.

(iii) The lowest lethal effects on egg hatching were found at temperatures between 62 to 73°F. and humidities of 53 to 93 per cent.

(iv) The optimum temperature for larval development (measured by the minimum time required to complete a given instar) decreased with successive instars.

(v) The larval feeding rate increased at higher temperatures, but although the early instars fed more rapidly in damp conditions, the 4th and 5th instars showed little humidity preference.

(vi) Pupal weight was greatest after larvae had been reared at about 50°F., at which temperature the assimilation rate was highest and growth slowest.

(vii) The most important result of the work has been the demonstration of the effect of subjecting the early larval instars to temperatures considerably below the optimum (Table 19). The considerable lengthening of the last two stadia is evidently correlated with some change in the basal metabolism associated with the earlier exposure to sub-optimal temperatures. These induced changes in metabolism suggest that future work should be directed towards an investigation of similar alterations in disease resistance.

Table 19

	Duration of instars IV and V at optimum temperatures (days)
Instars I-III maintained at optimum temp. 70° F.	28
Instars I-III maintained at 50° F.	73

The studies on feeding intensity in the forest, where a constant larval population was maintained above a coprometer, by ringing shoots with vaseline, showed that there are two peaks of feeding activity. The principal one occurred between 21.00-02.00 hours with a smaller, diurnal peak between 08.00-13.00 hours. The most suitable conditions for rapid feeding seemed to be mild, damp nights, whilst the deleterious effect of cool rainy weather was very marked.

The general conclusion has been drawn that the preference of *Bupalus* for dry areas is apparent rather than real, for it is adapted to a wide climatic range. The general resistance of the larvae to disease in drier situations may be the limiting factor restricting outbreak areas.

STUDIES OF THE MORPHOLOGICAL VARIATION OF FOREST TREES

By Dr. E. V. LAING and Dr. A. CARLISLE
Forestry Department, Aberdeen University

European larch 165.51

Some work has been done on the anatomy of the leaves of what are considered to be recognised races of European larch. Special points of comparison include thickness of cuticle, development of hypodermis, cells of endodermis and extent of sclerenchyma formation. This entails the sectioning and examination of a great number of leaf sections.

Douglas fir

Some further work has been done on the variations in Douglas fir. Attempts have been made to correlate leaf anatomy and leaf arrangement with cone type.

Lodgepole pine

Work on the lodgepole pine, *Pinus contorta*, has been continued in this species on the lines stated in the 1955 *Report.*

Silver fir

Hybrids between *Abies alba* and *A. nordmanniana*, and between *A. alba* and *A. cephalonica* have been recorded as existing in our woodlands and policy woods. Those hybrids are *A. bornmuelleriana* and *A. borisii-regis*. The points of distinction have been given in *Scottish Forestry*, Vol. 10, p. 20.

Scots pine

The period 1955-56 was spent in the preparation of a publication concerning the native pine forests of Scotland, covering the morphology of the pines, the general ecology and the history.

Three more hitherto unrecorded remnants of native pinewoods were located on the west coast, namely, those at:

> Shieldaig, near Loch Torridon, Wester Ross; Barisdale, by Loch Hourn, Inverness-shire; Ardgour, Argyll.

The two first-named areas are the most westerly stands of native pine in Great Britain.

Birch

Preliminary inspections of birchwoods were carried out in north and north-western Scotland, confirming the findings of 1954-55 that, whilst many of the trees were ***Betula verrucosa*** and ***B. pubescens***, the majority exhibited characters intermediate between the two.

SHELTERBELT RESEARCH

By Dr. J. M. CABORN
Forestry Department, Edinburgh University

266

THE ULTIMATE OBJECT of the shelter research project is the determination of the most suitable sites, types, structures and maintenance methods for shelterbelts, so as to ensure maximum sheltering efficiency, particularly in connection with stock-rearing and afforestation on exposed hill and upland areas. During the first three-year period, completed in the course of the year, the programme was directed towards examination of the influences exerted by shelterbelts on the microclimates of adjacent areas. The second phase will be concerned with the practical utilisation of the microclimatic evidence available, in connection with the design, establishment and treatment of shelterbelts.

Shelterbelt Structure

It appears from the early investigations that the maintenance of a suitable structure in a shelterbelt can be controlled by the application of micro-climatological evidence, particularly of wind abatement, to silvicultural technique. Periodic investigations of wind conditions in the vicinity of a shelterbelt provide a ready indication of sheltering efficiency, and can ensure that the maximum protective value is being obtained from the belt. According to the 'penetrability' class in which the belt falls, and the degree of permeability desirable in each particular case, it should be possible, after due consideration of the site factors and the silvicultural condition, to prescribe the appropriate cultural treatment, whether this be thinning, re-stocking or improvement of the margins.

The design and regulation of the structure in a shelterbelt must be based on the two objectives of maintaining the penetrability ratio (and, hence, the sheltering influence of the belt) and preserving the general well-being of the stand. With the limited extent of the average shelterbelt, particularly in regard to width, silvicultural treatment presents a much more complex problem than is likely to be encountered in the normal run of plantations.

Several facts of silvicultural interest emerge from the studies of belt structures to date. Of these, probably most important is the fact that, in order to maintain the required degree of penetrability in a belt structure throughout the year, a vegetative composition which allows maximum flexibility is desirable. This suggests the intelligent use of mixtures, a good windward margin, probably of shrubs or small tree species, and the treatment of the shelterbelt as an ecological unit. Where pioneer species are used on an exposed site, eventual replacement must be considered at the outset and the planting scheme might be arranged accordingly. The importance of a reasonably close windward margin, especially near ground level, is also evident. A belt which is very open below produces excessive draughts and unfavourable climatic conditions within the belt, and complicates any underplanting or interplanting inside the belt. A further point is that the incidence of side illumination, particularly in a fairly narrow belt, may favour regeneration operations provided there is some protection against the dangers of excessive insolation. Very light openings in the overhead canopy may be sufficient for the artificial introduction of new species.

Experience has also shown that many belts may exhibit a remarkably high degree of efficiency in reducing wind velocity, and yet be in serious need of treatment from the point of view of preservation of the structure. Even-aged belts of conifers, often in urgent need of thinning but with no marginal cover near the ground, frequently come into this category.

Field Work

In the field work, attention is being focussed on the detailed examination of the composition and structure of existing belts, and an assessment, according to their particular function and location, of their continuous effectiveness and general well-being. Inevitably these investigations must be considered long-term. The structural problems of rehabilitating derelict and degraded belts form an important part of the research programme; experimental treatment of selected areas is expected to be carried out in conjunction with these studies. Wherever possible, periodic measurements of local wind conditions are being used as an indication of the efficiency registered by shelterbelts under examination. Experimental technique in this direction continues on the lines mentioned in the last annual report.

Planting stocks are being built up gradually for the experimental treatment of existing belts, and for the introduction of certain species, which are not readily obtainable from the trade, into new belts. Such species may be required, for example, in the creation of wind-resistant margins.

With the co-operation of the Department of Agriculture for Scotland and individual landowners and occupiers, the establishment and development of new shelterbelts, planted under subsidies provided for in the Hill Farming and Livestock Rearing Acts, are being studied.

Finally, it is anticipated that this research will be integrated with research proceeding in allied fields, notably that of animal husbandry, in an attempt to determine the type of shelter which is most beneficial to grazing animals on hill areas.

PART III

Reports on Results of Individual Investigations

PRELIMINARY TRIALS OF A QUICK METHOD FOR ESTIMATING THE SEED CONTENT OF CONES

By G. BUSZEWICZ and G. D. HOLMES

232.311

WHEN ORGANIZING cone collections on any appreciable scale, it is desirable to have some knowledge of the likely yield of seeds from a given volume of cones, both as a guide to the quantity of cones to be collected and to avoid wasteful collection of useless or low yielding cones. For generations it has been a common practice for foresters to examine cones for seed content by opening up a few sample cones with a pocket knife. Such a test enables a crude estimate to be made of the quality, i.e. soundness, of the seed, and with experience a very rough estimate of the likely seed yield may be possible. This method is better than no test at all, but at best it is crude and subjective.

In 1926, Penz (1926) suggested an improvement involving the use of a specially designed knife with which sample cones could be cut in half longitudinally with speed and accuracy. For Scots pine, he indicated that counts of seed exposed on the cut surface of each cone could be related to the actual seed content of the cone, and in turn, if the cone sample is representative, to the likely seed yield per hectolitre of cones. More recently, McWilliams (1950) 1950, in a guide to seed collectors, describes a method of judging the cone quality of Douglas fir according to the number of well-filled seeds on cut sample cones.

Given further information on the relation between the seed number visible on cones cut in the radial longitudinal plane, and actual seed yield, the method seems to have real practical possibilities as a field test. Accordingly in late 1954 and 1955 a small investigation was carried out to examine the technique for Scots pine and Corsican pine in Britain.

Apparatus

A special cone cutting knife consisting of a modification of a design described by Tyszkiewicz (1952) was constructed (see Fig. 1) to enable cones to be cut cleanly and accurately in half. As can be seen in the illustration, the tool consists of a curved steel knife pivoted on an adjustable fulcrum point in an arched knife guide. The knife is held rigidly in its cutting plane by the arched guide, and the shaped wooden block on the base plate centres the cone for cutting in a groove.

When in use, the cone is placed in position on the divided wooden block, and the knife lowered under steady pressure so that the blade passes through the cone into a slot in the metal base plate. The curved blade, and the design of the supporting arched guide, give a slicing action through the cone, ensuring a clean cut. An earlier model with a straight blade was not so successful. By adjustment of the fulcrum point the curved knife can be used to give a clean cut through cones of a wide range of size and toughness.

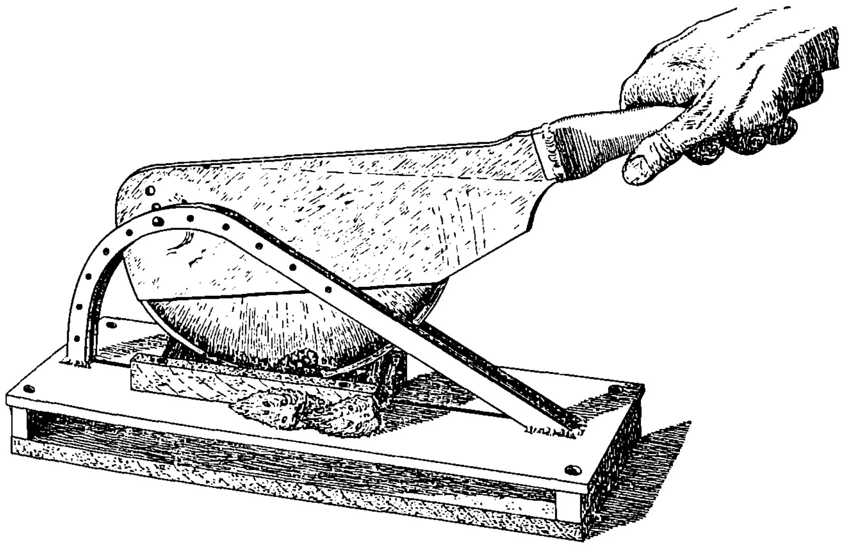


FIG. 1. Cone Cutting Knife.

Experimental Procedure

Cone samples of half a bushel each were collected from a number of stands of Scots pine and Corsican pine at two seasons, namely, October, 1954, and January, 1955. Samples were collected from the following areas selected as representative of the main climatic regions where the species are grown, as follows:

Scots pine:	1. West Scotland	(Benmore Forest)
	2. North ,,	(Seafield Estate)
	3. East ,,	(Speymouth Forest)
	4. ,, ,,	(Altcailleach ,,)
	5. East England	(Rendlesham ,,)
	6. South and South East England	(Bramshill ,,)
	7. ,, ,, ,, ,, ,,	(Alice Holt ,,)
	8. ,, ,, ,, ,, ,,	(New Forest)
Corsican pine:	1. East England	(Rendlesham Forest)
	2. North West England	(Delamere ,,)
	3. South and South East England	(Bramshill ,,)
	4. ,, ,, ,, ,, ,,	(New Forest)

On receipt, each cone lot was divided at random to provide material for the following operations:

(1) Kiln Extraction—(4 x 50 cones). The seeds were extracted separately from each 50-cone lot, using a forced draught kiln at a temperature not exceeding 113°F. After extraction the seed was de-winged and weighed prior to germination test.

(2) Cone cutting and examination—(4 x 50 cones). Cones were cut and the number of full seeds visible on each cut section recorded.

Results

The results of the above determinations for both species and collection dates are summarised in Table 20 below:

Numbers and Weight of Seeds in Cones of Scots Pine and Corsican Pine in Relation to the Results of Examination of Samples of Cut Cones

Table 20

Species (1)	Sample No. (2)	Av. No. Full Seeds per cut Surface (x) (3)	Total Weight of Seed (grms) per 100 cones (Y_1) (4)	No. Sound Seeds per 100 cones (Y_2) (5)	Total No. Seeds per 100 cones (Y_3) (6)
Scots Pine	1	0.96	6.54	1122	1486
	1a	0.82	5.18	538	1493
	2	2.05	5.26	820	1105
	2a	1.51	8.36	1036	2206
	3	2.89	14.62	2092	2547
	3a	1.61	4.92	704	998
	4	1.77	7.46	1134	1780
	4a	0.96	6.74	768	1737
	5	3.83	22.06	2814	3535
	5a	3.19	19.68	2752	3129
	6	3.85	23.14	2506	3196
	6a	3.21	19.78	2264	3081
	7	3.96	12.32	1908	2499
	7a	2.43	15.64	1846	2646
	8	1.19	4.12	646	1241
	8a	1.51	4.75	838	1724
Corsican Pine	1	3.42	48.0	3100	4120
	1a	2.66	55.62	2310	4045
	2	0.53	18.12	358	2199
	2a	0.68	19.98	530	2482
	3	1.08	24.32	824	2834
	3a	1.29	22.30	686	2191
	4	1.40	40.34	1196	5379
	4a	1.01	29.64	1202	4365

(*Note:* In column (2), a sample number alone relates to samples taken in October, 1954. Numbers followed by letter "a" indicate samples taken in January, 1955).

The figures in column 3 (x) represent the average of counts of sound seed per cone apparent on the cut surface of each sample. The figures in columns 4, 5, and 6 (Y_1, Y_2 and Y_3) were determined on the seed extracted in the kiln on parallel samples.

Both species showed a fair proportion of empty seeds, as can be seen by comparing the figures Y_2 and Y_3 in Table 20. Corsican pine had the highest and most variable proportion of empty seeds in relation to total seed yield, but in both species the variation in the amount of empty seed was sufficient to invalidate comparison of x and Y_3.

The correlation coefficients for each of the main comparisons with sound seeds per cut cone (x) are shown in Table 21.

Table 21 *Correlation Co-efficients*

Determination per 100 cones	Scots Pine	Corsican Pine
Total weight of Seed (Y_1) (grms)	0.87	0.88
No of Sound Seeds (Y_2)	0.90	0.97
Total No. of Seeds (Y_3)	0.83	0.46

There was a highly significant correlation between x and total weight of seed per 100 cones (Y_1) and number of sound seeds per 100 cones (Y_2); equations have been calculated for estimation of the values of Y_1 and Y_2 from the value of x. In the case of Scots pine, regression lines were first calculated through the means, but since they passed close to the origin a better estimate is likely to be obtained with the line calculated to pass through the origin (see Fig. 5). The amended equations for Scots pine are:

$Y_1 = 5.1$ x (Standard Error of regression coefficient $= 0.36$)

$Y_2 = 660$ x (,, ,, ,, ,, ,, $= 33$)

For Corsican pine the regression line passed close to the origin only for comparison with Y_2, and the regression equations calculated were:

$Y_1 = 12\,x + 13.8$ (Standard Error of regression coefficient $= 2.71$)

$Y_2 = 867$ x (,, ,, ,, ,, ,, $= 47$)

Graphs have been drawn for each of the equations of estimation and these are shown superimposed on the actual points in Figs. 2 to 6.

It seems apparent from these figures that the average number of sound seeds exposed on the radial longitudinal cut surface of cone samples can be utilised as a basis for estimation of the number of sound seeds and the weight of seed which can be extracted from a given number of cones. Extension of this technique for estimation of the potential yield of seed per *bushel* of cones is more difficult owing to a large variation in cone size and the number of cones per bushel. If a reasonable estimate is to be made it is necessary to measure the number of cones per bushel for the sample examined. The observed numbers of cones per bushel in the present trial were as shown in Table 22.

Table 22 *Cones per Bushel*

Species	Number of Cones per Bushel		
	Range		Average
	Lowest	Highest	
Scots pine	1500	4000	2000
Corsican pine	500	1500	1000

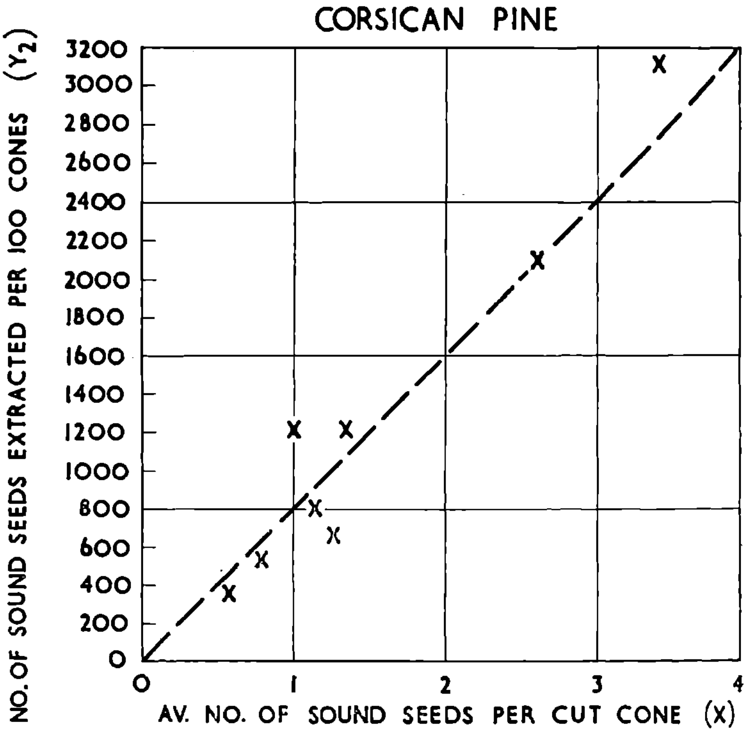


FIG. 2. Corsican Pine: Total Weight of Seed, in Grams per 100 Cones, in Relation to Average Number of Sound Seed Apparent on a Cut Cone Sample.

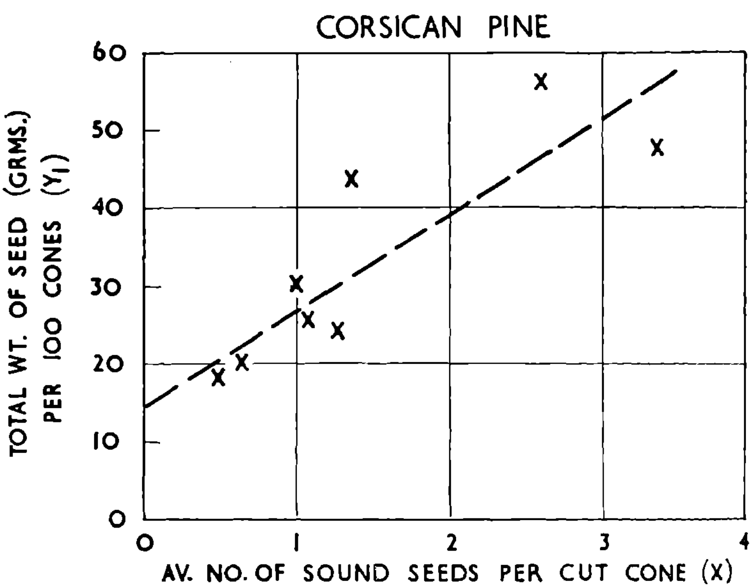


FIG. 3. Corsican Pine: Number of Sound Seeds Extracted from 100 Cones in Relation to Average Number of Sound Seed Apparent on a Cut Cone Sample.

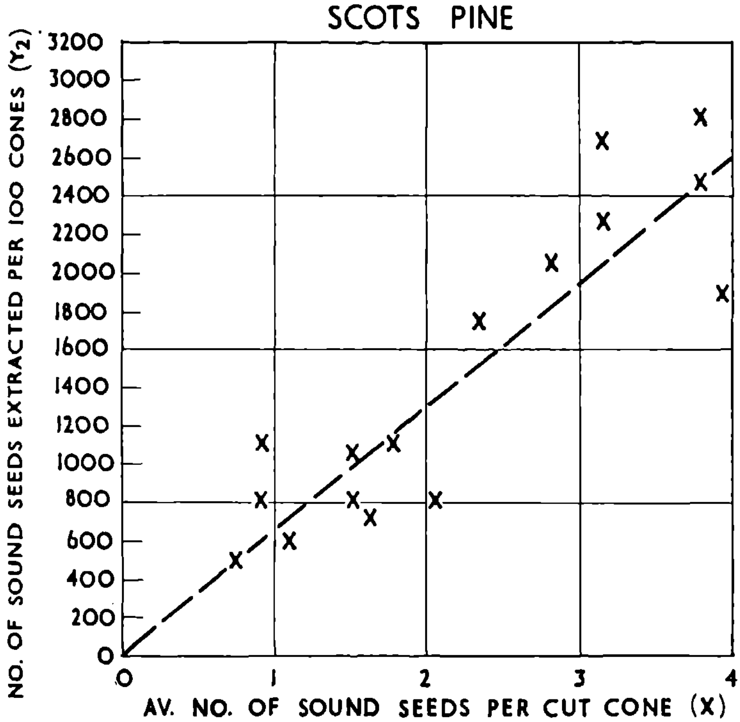


FIG. 4. Scots Pine: Total Weight of Seed, in Grams per 100 Cones, in Relation to Average Number of Sound Seed Apparent on a Cut Cone Sample.

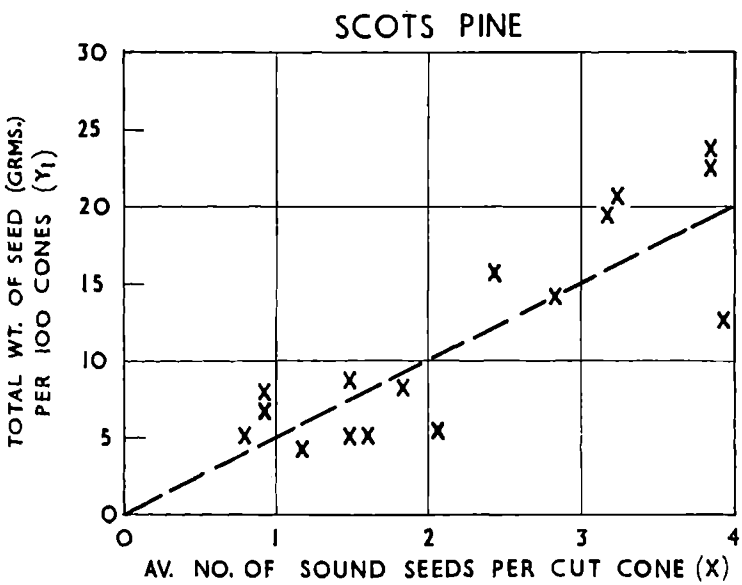


FIG. 5. Scots Pine: Number of Sound Seeds Extracted from 100 Cones, in Relation to Average Number of Sound Seed Apparent on a Cut Cone Sample.

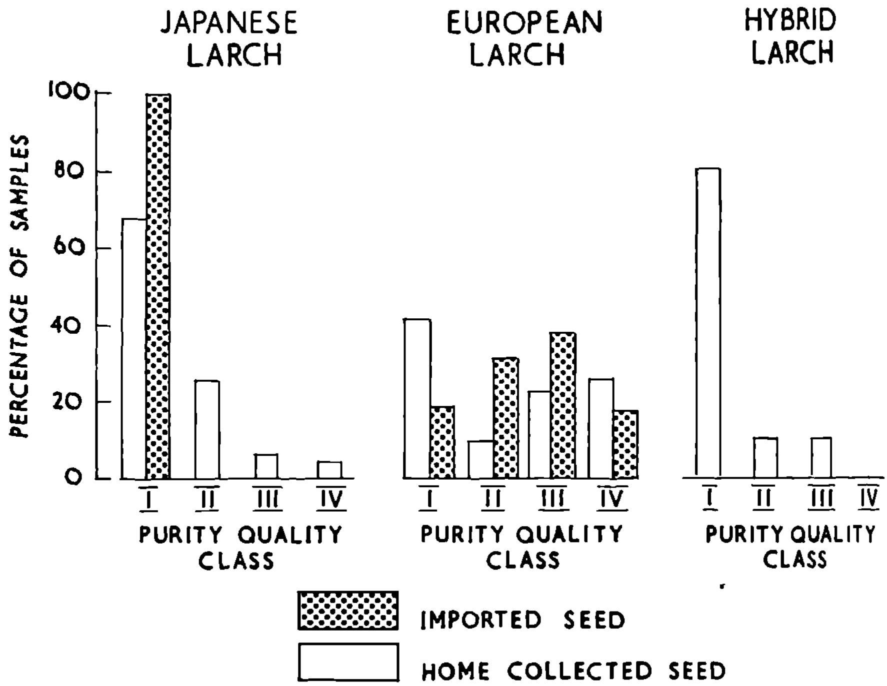


FIG. 6. Histogram Showing the Percentage of Imported and Home-Collected Seed Samples in Four Purity Classes. (See pp. 106-107)

Using the regression equations given above a provisional table of likely seed yield may be constructed as follows according to the number of cones per bushel and the average number of sound seeds per cut surface:

Estimated Yield of Sound Seed per Bushel of Cones

Table 23 Ounces

Av. number of full seeds per cut cone surface (x)	No. of Cones per Bushel					
Scots pine	1500	2000	2500	3000	3500	4000
	Ounces of seed per bushel					
1	2.0	3.0	3.5	4.0	5.0	5.5
2	4.0	5.5	7.0	8.5	10.0	11.0
3	6.5	8.5				
4	8.5	11.0				
Corsican pine	500	750	1000	1250	—	—
	Ounces of seed per bushel					
1	2	3	4	5		
2	4	6	8			
3	6	9				
4	8					

Such a table based on so few data is very conjectural, and the next stage in the investigation for these species will be to check these values on as many cone consignments as possible passing through the extraction plants. These results are considered sufficiently promising to justify extending the study to other species in the near future, with the aim of developing a simple procedure for use in the field. Examination of the germination quality of the sound seed extracted in the course of these trials showed interesting differences between the two dates of collection for some origins.

Germinative Capacity of Sound Seed in Relation to Origin and Collection Date
Table 24

Species	Origin	Germin. Capacity per cent of Sound Seed Extracted	
		Collected Oct. 1954	Collected Jan. 1955
Scots pine	West Scotland	29	84
	North „	27	87
	East „	45	60
	„ „	74	78
	East England	82	90
	S.E. „	97	98
	„ „	95	90
	South „	96	90
	Average:	68	85
Corsican pine	North England	18	77
	East „	62	93
	S.E. „	70	97
	South „	70	61
	Average:	55	82

Many of the seeds from cones collected in October, 1954, showed a lower germination quality than seed from January, 1955, collections. This applies particularly to the most northern origins examined, which suggests that these seeds were incompletely ripened or more liable to extraction injury than when collected in October. This observation confirms the normal recommendation that cones of these species should not be collected before November or December.

Summary

(1) Trials have been made with a method of judging the seed content of cones by cutting sample cones lengthwise through the centre. This exposes a number of seeds in cross section, which can be counted and related to the actual seed content of the cones.

(2) A special knife designed to cut cones accurately in half to facilitate seed counts is described and illustrated.

(3) Examination of the method for a number of samples of Scots pine and Corsican pine showed a good correlation of the average number of sound seeds visible on a cut cone with the number of sound seeds in the cones and the total weight of seed extracted. A provisional table is given for estimation of the likely yield of sound seed per bushel.

(4) It is proposed to check these conclusions for Scots pine and Corsican pine by further measurements, and the work will shortly be extended to other species with a view to development of a simple field procedure.

REFERENCES

McWilliams, H.G. *Collecting Seed from Forest Trees.* B.C. Forest Service Public. No. B. 41. 1950.

Penz, K. Vervollkommungen in der Gervinnung von Nadelholzsamen. *Zeit. fur Forst. und Jagd.* 58, p. 197-225, 1926.

Tyszkowicz, S. *Nasiennictwolensne,* Warsaw, 1952.

SUMMARY OF FIVE YEARS' EXPERIENCE OF SEED TESTING FOR LARCHES

By G. BUSZEWICZ and G. D. HOLMES

Introduction 232.318

The three larches most commonly planted in Britain are European larch (*Larix decidua.* Mill.), Japanese larch (*L. leptolepis* Sieb. and Zucc.) Murr., and hybrid larch (*L. eurolepis* A. Henry). The species are of considerable economic importance, and at present the larches account for about 14 per cent of the trees planted annually by the Forestry Commission. This represents a total of over 18 million larch plants each year, of which about 90 per cent are Japanese larch.

The production of such numbers of plants involves the sowing of considerable quantities of seed each year, most seed consignments being tested for purity and germination quality at the Alice Holt Seed Testing laboratory before sowing. A total of 360 seed samples, each representing up to 200 lb. of seed in store, have been tested during the last five years, and the results summarised below provide a useful indication of the standards of seed quality for the three species. It will be noted that data has been presented separately for imported and home-collected seed of each kind, as this brings out interesting comparisons.

The seed testing methods employed for larch have been those prescribed for the species by the International Seed Testing Association in the International Rules for Seed Testing (Anon., 1953).

These rules prescribe identical methods for purity and germination tests for all species of larch, and a free choice of one of four different germination substrata is given. At Alice Holt, all purity tests have been completed by the 'Quick Method' as required by the Rules, and germination tests have been carried out using a Copenhagen tank (Jacobsen), germinator controlled at an alternating temperature of 20 to 30°C. (68-86°F.) for 28 days. Germination counts are made every seven days, and any ungerminated sound seeds remaining at the end of the test period have been examined by the tetrazolium biochemical method as a test of viability. The results of this tetrazolium test have been presented as a separate 'plus figure' after the actual germination per cent (e.g. 35% +5%). In addition, a determination of the weight of one thousand seeds was completed for all samples to allow calculation of seed numbers per pound.

The results of these tests, extending over the five-year period, are discussed below under the headings of seed purity, seed germination, and seed weight.

Seed Purity, or Cleanliness

Results of all purity tests have been divided into four arbitrary quality classes, as follows, according to the pure seed percentage in the samples:

Quality	*Pure seed per cent (by weight)*
I	Over 90 per cent
II	81-90 per cent
III	71-80 per cent
IV	Less than 70 per cent

The numbers and percentage of samples of each species by purity classes below presented in Table 25 and Figure 6. (See page 104.)

Seed Purity Tests, Classifications of Samples into Four Purity Classes

Table 25

Quality Class (Purity Percentage)	Number of Samples							
	Japanese Larch			European Larch			Hybrid Larch	
	Home Collected	Imported	Total	Home Collected	Imported	Total	Home Collected	—
I, over 90 per cent	47	117	164	29	8	37	23	—
II, 81-90 „ „	16	0	16	7	14	21	3	—
III, 71-80 „ „	4	0	4	16	15	31	3	—
IV, Less than 70 per cent	2	0	2	19	8	27	0	—
Total	69	117	186	71	45	116	29	—

It can be seen that the species differed considerably in seed purity. European larch showed low percentages of pure seed, and only 37 out of 116 samples received had purity figures over 90 per cent; there was a considerable proportion of samples below 70 per cent purity. Both Japanese and hybrid larches had consistently high purity values, an average of 89 per cent and 80 per cent of samples respectively, having over 90 per cent pure seed.

Comparison of imported and home-collected seed showed that imported seed of Japanese larch was of high quality, all samples containing more than 90 per cent pure seeds. Home-collected seeds were rather poorer in this respect. For European larch, the number of Quality I samples was low, but in this case home-collected seed contained the highest proportion of samples with purity values over 90 per cent. The standard of purity for Japanese and hybrid larch is high, but when compared with the excellent quality of imported Japanese larch seed, there is clearly room for improvement in the techniques of cleaning home-collected seed lots. For European larch, the standard of purity is very low, and this species contains more impurities than any other common conifer. This is largely due to difficulty in extracting seed from the cones in this species, and a large part of the impurities consist of fragments of cone scale of a size which are difficult to separate in the seed cleaning plant. This fact is of importance, as low purity figures affect the numbers of seed per pound and the sowing value of the seed, independently of the germination quality of the pure seed fraction.

Seed Weight

Seed weight determinations were made by weighing four replicates of 100 pure seeds from each sample, for estimation of the number of pure seeds per pound, which, together with the purity percentage, enables calculation of the number of pure seeds per pound of an unsorted sample. The results of these weight determinations are presented in Table 26.

The following definitions were used in this connection:

Pure Seed refers to mature undamaged seed of the species concerned and also includes shrivelled or immature seeds, and pieces of seeds resulting from breakage that are more than one-half their original size.

Unsorted Seed refers to the seed as received for test, and includes pure seeds together with all impurities such as cone fragments, resin, seed wings, etc.

Seed Weight: The Average and Range of Seed Numbers per lb. of Clean Seed and per lb. of Uncleaned Seed

Table 26

Species	Origin	Number of Pure Seeds (Thousands) per lb.						Basis (No. of Samples)
		A. Pure Seed			B. Unsorted Seed			
		Average	Low	High	Average	Low	High	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Japanese Larch	Home Collected	115	82	166	104	49	166	69
	Imported	124	95	139	120	87	139	117
European Larch	Home Collected	94	78	127	76	35	126	71
	Imported	93	65	111	75	44	110	45
Hybrid Larch	Home Collected	108	82	130	101	58	129	29

Columns (3), (4) and (5) give the most accurate impression of seed weight, while columns (6), (7) and (8), which take into account purity percentage as well as seed weight, give the most useful picture of the value of the seed in practice.

From inspection of columns (3), (4) and (5), it can be seen that European larch has rather heavier seed than the other two species, but there is no great difference in seed weight between home-collected and imported lots for this species. Japanese larch on the other hand has the smallest seeds, and there is an appreciable difference between imported and home collected seed in this respect. Home-collected seed of Japanese larch is on average heavier, but more variable in seed weight than seed imported from Japan. Hybrid larch appears somewhat intermediate in seed weight between the two parent species.

Pure seed weight includes both sound and empty seeds, and from the high proportions of empty seeds reported in Tables 27, 28 and 29, it might appear that the high "empty seed" fractions would tend to increase the numbers of pure seeds per pound. In actual fact, empty seeds of larch weigh nearly as much as sound seeds, and according to Schmidt (1929), the relative weight of empty and full seeds is more or less constant within the species. Thus for European larch the weight of a given number of empty seeds is 77 per cent of that of the same number of sound seeds. Empty seeds of most other conifers are much lighter than sound seeds, e.g. for Scots pine, empty seeds have only 25 per cent of the weight of full seeds. These points help to explain the consistently high percentage of empty seeds found in most consignments of larch. The small differences in seed density between empty and full seeds makes it almost impossible to segregate them in the cleaning process by normal seed blowing methods.

Japanese Larch

Seed Germination. Classification of Samples into Germination Quality Classes, showing Averages of Germinative Capacity, Germination Rate and Empty Seed Percentage

Table 27

Quality Class (Germinative Capacity Percentage)	No. of Samples	Percentage of Samples		Germination Percentage			Germination Rate (Seed Germinated as Percentage of Total Viable Seeds)					Empty Seed Percentage
				Days			Days					
				21	28	28*	7	10	14	21	28	
A. Home Collected Seed:												
I (over 50 per cent)	19	28		58	60	61	10	39	75	95	98	32
II (31-50 „ „)	20	29		40	41	42	9	43	78	98	98	51
III (11-30 „ „)	23	33		20	21	21	9	48	81	95	100	65
IV (1-10 „ „)	7	10		4	4	5	0	20	40	80	80	81
Total:	69	100	Av.:	35	36	36	11	42	78	97	100	52
B. Imported Seed												
I (over 50 per cent)	5	4		32	36	53	2	19	38	60	68	38
II (31-50 „ „)	74	64		27	30	39	2	15	41	69	77	50
III (11-30 „ „)	32	27		16	19	23	0	4	35	70	83	44
IV (1-10 „ „)	6	5		2	4	5	0	0	20	40	80	33
Total:	117	100	Av.:	23	26	34	0	12	41	68	76	45
C. Imported Seed after Pre-Chilling 21 *Days at* 2° *C.* (36°F.)												
I (over 50 per cent)	10	36		58	59		54	83	95	98		
II (31-50 „ „)	13	46		43	43		53	86	95	100		
III (11-30 „ „)	2	7		16	16		31	56	88	100		
IV (1-10 „ „)	3	11		3	4		25	50	75	75		
Total:	28	100	Av.:	42	43		51	81	93	98		

Note: Column headed 28* under 'Germination percentage' represents germination percentage at 28 days and viable ungerminated seed as determined by tetrazolium test.

Seed Germination Quality

Examination of the germinative capacity and rate of germination reveals several important differences between species and origins of seed. For purposes of summary all results of germination tests have been divided into four arbitrary quality classes, as follows:—

	Germinative Capacity Percentage
Quality I	Over 50 per cent
„ II	31-50 per cent
„ III	11-30 per cent
„ IV	1-10 per cent

In addition, all data are presented separately for home and imported seed origins. Results are summarised by species in Tables 27, 28 and 29:

European Larch
Seed Germination. Classification of Samples into Germination Quality Classes. Showing Averages of Germinative Capacity, Germination Rate, and Empty Seed Percentage

Table 28

Quality Class (Germinative Capacity Percentage)	No. of Samples	Percentage of Samples		Germination Percentage			Germination Rate (Seeds Germinated as Percentage of Total Viable Seeds)					Empty Seed Percentage
				Days			Days					
				21	28	28*	7	10	14	21	28	
A. Home Collected Seed:												
I (over 50 per cent)	0	0		—	—	—	—	—	—	—	—	—
II (31-50 „ „)	7	10		33	33	33	79	97	100	100	100	60
III (11-30 „ „)	51	72		19	19	19	74	95	100	100	100	73
IV (1-10 „ „)	13	18		7	7	7	57	86	100	100	100	89
Total:	71	100	Av:	18	18	18	72	94	100	100	100	75
B. Imported Seed:												
I (over 50 per cent)	6	13		57	58	58	71	93	95	98	100	34
II (31-50 „ „)	21	47		39	39	39	69	90	97	100	100	49
III (11-30 „ „)	14	31		19	19	19	53	79	95	100	100	67
IV (1-10 „ „)	4	9		6	7	7	29	29	71	86	100	56
Total:	45	100	Av:	32	33	33	63	85	94	97	100	52

Note: '28*', see footnote to Table 27.

Japanese Larch (Table 27)

In terms of average germinative capacity (col. 6), both home and imported seed were of similar quality, i.e. averaging 36 per cent and 34 per cent germination respectively. There was, however, a considerable difference between home and imported seed in the *rate* of germination (see columns (7) to (11)). In the case of home seed, almost all viable seeds had germinated in 28 days, compared with only 76 per cent of viable seeds for imported seed.

Under these test conditions, imported seeds are definitely slower germinating than home origins and may require a modified technique of test. During the past two years, trials have been made involving pre-chilling the seed at 2°C. (36°F.) for a period before germination, as described for Sitka spruce and Douglas fir (Holmes and Buszewicz, 1954). The results of trials for Japanese larch are summarised in Section (C) of Table 27, and indicate that complete germination can be obtained in 21 days, if the sample is first exposed to moist pretreatment for 21 days at 2°C. (36°F.). This technique has proved satisfactory in practice, and it has now been adopted as a routine procedure to cut the test period to 21 days for Japanese larch.

Inspection of column (3) of Table 27 shows that imported seed was the most consistent in quality, nearly 65 per cent of samples having a germination between 31 per cent and 50 per cent, with very small numbers at the high and low end of the quality range. Home seed on the other hand was more variable, but over 35 per cent of samples were in the highest quality class. The percentage of empty seed was generally high, averaging 48 per cent over all samples.

Hybrid Larch

Seed Germination. Classification of Samples into Germination Quality Classes, showing Averages of Germinative Capacity, Germination Rate, and Empty Seed Percentage

Table 29

Quality Class (Germinative Capacity Percentage)	No. of Samples	Percentage of Samples		Germination Percentage			Germination Rate (Seeds Germinated As Percentage of Total Viable Seed)					Empty Seed Percentage
				Days			Days					
				21	28	28*	7	10	14	21	28	
I (over 50 per cent)	0	0		—	—	—	—	—	—	—	—	—
II (31-50 „ „)	6	21		35	36	36	42	72	89	97	100	60
III (11-30 „ „)	18	62		20	21	21	33	67	86	95	100	74
IV (1-10 „ „)	5	17		8	8	8	25	63	86	100	—	84
Total:	29	100	Av:	21	22	22	36	68	86	95	100	69

Note: '28*', see footnote to Table 3.

European Larch (Table 28)

European larch was of low germinative capacity, averaging only 24 per cent germination over all samples compared with 35 per cent for Japanese larch.

Home origins were particularly poor, averaging only 18 per cent germination, against 32 per cent for imported lots. However, as for Japanese larch, home collected seed germinated more rapidly than imported seed, which required one week longer for completion.

It appears from these results that a test period of 21 days is adequate for germination of European larch without the necessity of seed pretreatment. The percentage of empty seed was very high, particularly for home-collected seed which averaged 75 per cent empty, rising to 89 per cent for lower germination qualities. Imported seed was rather better, but here also there was a high average of 53 per cent empty seed.

Hybrid Larch (Table 29)

Hybrid larch averaged 22 per cent germination, appearing rather similar in germination quality to home-collected European larch. Germination rate was somewhat slower and a 28-day test period has been the rule.

For European larch, there have been no difficulties in securing rapid and full germination under the test conditions provided, and there seems little justification for continuing the test longer than 21 days. Closely similar results were obtained by Rohmeder (1953), who reported that only 0.3 per cent increase of germination occurred between the 21st and 28th day of test.

Hybrid larch, and particularly Japanese larch, show slower rates of germination, imported seed of Japanese larch being appreciably slower than home seed. Rohmeder (1953), noted the generally slow germination rate of Japanese larch compared with European larch, which led him to study the relative respiration rates and thickness of the seed coat. He found that the seed coat of European larch is twice as thick as that of Japanese larch, but despite this after six days in a germinator the seeds respire at three times the rate of Japanese larch seeds. Following these observations, we suggest that the slight dormancy of Japanese larch is situated in the embryo. Because of the slow rate of germination, Rohmeder suggested a test period of 42 days for Japanese larch. Tests have been continued for this period on many occasions at Alice Holt, but owing to the incidence of mould growth after such a long period, it is considered preferable to pre-chill the seeds 21 days at 2°C. (36°F.), followed by 21 days in the germinator. The total period is the same, but the period for mould development is reduced by half as the seeds develop more rapidly.

The Copenhagen tank (Jacobsen) germinator appears well suited for germination of larch species, and it is in fact the most commonly used method for these species throughout the world. Seeds are exposed to light throughout this test, but no close study has been made of the influence of light on the germination of these species. Rohmeder (1939, 1951) found that light was not a critical factor for germination of European larch, but this point was not examined for hybrid and Japanese larch.

Summary

(1) The report describes the results of purity, weight, and germination tests for 360 samples of larch seed examined during the period 1951-1956 at the Alice Holt Seed Testing Laboratory. Results are compared for home collected and imported seed of European larch and Japanese larch, and home origins of hybrid larch.

(2) Summary of seed purity and weight determinations showed up appreciable differences between species and origins of seed. One of the most outstanding features was the high percentage of empty seeds in all species, which is a reflection of the difficulty in seed cleaning owing to the small

difference in seed density between full and empty seeds. This point was especially evident for home collected European and hybrid larch.

(3) Germination tests showed that European and hybrid larch germinate more rapidly under laboratory conditions than does Japanese larch, and on the basis of the experience reported the following test conditions are recommended:

European larch—Copenhagen (Jacobsen) germinator at an alternating temperature 20-30°C. (68-86°F.) for 21 days.

Hybrid larch, as for European larch, but continue 28 days.

Japanese larch—as for European larch, but 21 days' test preceded by moist pretreatment at 2°C. (36°F.) for 21 days.

REFERENCES

Anon (1953) International Rules for Seed Testing. *Proc. Int. Seed. Test. Assoc.*

Holmes, G. D., and Buszewicz, G. (1954). *For. Comm. Rep. For. Res.* 1954, pp. 84-91.

Rohmeder, E. (1939). *Forstwiss. Cbl.* 61, pp. 393-406.

„ „ (1951) *Beiträge zur Keimungsphysiologie der Forstpflanzen.* pp. 57-81 and pp. 122-140.

„ „ (1953). *Forstwiss Cbl.* 72, pp. 210-220.

Schmidt, W. (1929). *Forstarchiv.* pp. 81-85.

EXPERIMENTS ON SEEDBED COMPACTION

By R. FAULKNER

232.323.6

IN SCOTLAND in 1951 a survey was made of the various methods of compacting nursery seedbeds in eleven of the larger conservancy nurseries, to find out what the current practices were. In some instances it was believed that under-compaction of the soil might be one of the factors contributing to low seedling production, due to the earlier breakdown of capillary water supplies during periods of spring and summer drought. Data from the survey showed wide variations in the methods of compaction and the equipment used. The information obtained is summarised in Table 30.

Because of this wide variation in methods it was decided to start a series of experiments extending over three years to compare the effects of various pre-sowing compaction treatments, using rollers of similar diameters but of varying weights. Treatments were included to determine the merits of firming the seed into the seedbed surface after sowing, and of compaction of the seedbeds after sowing and grit covering.

Experiments to Compare Various Seedbed Compaction Treatments

The definition of the object of the experiment was:

To determine the effect of different degrees of seedbed compaction, including compaction before and after sowing and compaction after covering seed, on the height growth and total yield of seedlings.

Types and Weights of Rollers and Times of Use in Eleven Northern Nurseries

Table 30

Roller	Approx. Weight Lb.	No. of Nurseries	Roller used		
			Before sowing	After sowing	After covering seed
Wood—Diameter 7 in.	45	1	YES	YES	NO
Wood—Diameter 7½ in.	52	1	NO	YES	NO
Wood—Diameter 9 in.	75	1	YES	NO	NO
Wood—Diameter 11 in.	112	2	YES YES	NO NO	YES NO
Wood—Diameter 12 in.	134	1	YES	NO	YES
Wood—Diameter 13 in.	160	3	YES NO YES	YES YES NO	NO NO YES
Wood—Diameter 15 in.	210	1	YES	YES	NO
Hollow Metal—Diameter 15 in.	140	1	NO - but foot tramping	YES	NO

The indicator tree species used was Sitka spruce. In 1952 an exploratory experiment was laid down in Wykeham nursery, Yorkshire. In 1953 the experiment was modified by using heavier rollers of smaller diameter and repeated at Inchnacardoch, Inverness-shire; Fleet, Kirkcudbrightshire; and again at Wykeham. It was again repeated in 1954 at the 1953 centres and also at the Bush, Midlothian.

The design of the experiment was a 4 x 2 x 2 factorial, consisting of sixteen plots replicated in three blocks. Four pre-sowing treatments (including no compaction) were combined with treatments in which seeds were, or were not, firmed into the seedbed surface; these again were combined with treatments in which plots were either rolled after covering or else were left unrolled.

Seedbeds were prepared in early spring, and basal dressings of superphosphate, and sulphate of potash, were given in sufficient amounts to ensure that deficiencies of phosphate and potassium nutrients would not limit growth. In July nitrogen top-dressings in the form of 'Nitrochalk' were given.

The size of each treatment plot was five feet by three feet six inches, of which the centre three feet square was sown. The additional one-and-a-half feet were required as a resting place for the roller while its weight was being increased or decreased. Sitka spruce seed was sown broadcast at 5.3 grams per square yard in 1952, but in 1953 and 1954 the sowing rate was adjusted to give a theoretical yield of 100 seedlings per square foot. After seed sowing the seed was covered with a suitable local grit to a depth of 3/16th inch.

Experimental Treatments used in the 1952 experiment at Wykeham were:

Seedbeds remaining uncompacted prior to sowing.

Seedbeds compacted before sowing with a 23-in. diameter roller weighing 1¼ cwt.*

Seedbeds compacted with a 23-in. diameter roller loaded to produce a downward thrust through the axle of 2¼ cwt.*

Seedbeds compacted with a 23-in. diameter roller loaded to produce a downward thrust through the axle of 3-3¼ cwt.*

Seeds left unfirmed after sowing and before covering with grit.

Seeds pressed into the soil with a 1 ft. x 1 ft. board until flush with the seedbed surface.

Seedbeds left unrolled after covering with grit.

Seedbeds rolled with a 1-1½ cwt. roller after covering with grit.

Soil Types and Condition at the Time of Compaction

The soil type at Wykeham can be described as a medium silty loam, whereas at Inchnacardoch the soil is a sandy loam with some gravel, and at Fleet it is a medium to heavy loam. At Bush nursery the soil is a sandy loam and at Inchnacardoch Heathland nursery it is a sandy loam with a small admixture of peat.

At all nurseries and in all years the seedbeds were prepared and compacted when the soil was easily cultivated with a machine cultivator, at a time when the soil was inclined to be slightly dry. However, at Wykeham in 1954 the spring period was exceptionally dry and seedbeds were prepared and compacted under very dry conditions, the result of which probably caused significant reductions in seedling yields.

Effect of Compaction Treatments on Germination

The exploratory experiment at Wykeham was sown in May. The blocks of the experiment were compacted and sown at weekly intervals, the whole experiment taking two weeks for completion. Two successive germination assessments were carried out, and when the data were averaged for the three blocks it clearly indicated that increased compaction, firming the seed into the bed surface, and rolling in the grit all speeded up the rate of germination (see Table 31).

In 1953 and 1954 similar evidence was obtained from the majority of the nurseries in which the experiment was repeated using heavier rollers. The data showed quite clearly that at the time of the first germination assessment, there were considerable and often highly significant ($p=0.01$) differences in the numbers of seedlings between compacted and uncompacted seedbeds. Seed firmed into the bed surface or beds which had been rolled after grit applications produced higher numbers of seedlings than seeds left unfirmed after sowing, and beds on which the grit had not been rolled in. In all cases added compaction produced greater numbers of seedlings.

Subsequent germination assessments at fortnightly intervals showed that differences in numbers of seedlings between the various treatments became progressively smaller as the growing season advances, and that they are seldom significant at the 5% level ($p. =0.05$) of significance.

---

* In 1953 and 1954 12 in. to 12½ in. diameter metal rollers were used at all centres. The unloaded rollers weighed 1 cwt. and loads to bring the weights up to 4 or 7 cwts. were used.

Table 31 *Germination Data. Wykeham Experiment 5/52*

Treatments		First Assessment Total Nos. per square foot		Second Assessment Total Nos. per square foot	
Uncompacted plots		29	S.E. ± 3	48	S.E. ± 3
Compacted with 1¼ cwt. roller		32		56	
„ „ 2¼ „ „		36		64	
„ „ 3¼ „ „		40		70	
Critical differences:	5%	8		11	
	1%	12		15	
Seeds unfirmed in bed surface		32	S.E. ± 2	56	S.E. ± 3
Seeds firmed into „ „		38		61	
Critical differences:	5%	Not significant		Not significant	
	1%	Not significant		Not significant	
Grit unrolled		32	S.E. ± 2	55	S.E. ± 3
Grit rolled		39		64	
Critical differences:	5%	Not significant		8	
	1%	Not significant		Not significant	

Effect of Compaction Treatments on Mean Heights of Seedlings

In the 1952 Wykeham experiment it was shown that increasing the degree of seedbed compaction produces corresponding progressive increases in heights of the seedlings. The increase in heights of seedlings raised on ground which had been firmed with a 3¼ cwt. roller, although slight, were highly significant in comparison with seedlings raised on uncompacted seedbeds. Firming the seeds into the seedbed surface after sowing, and lightly rolling the seedbeds after covering with grit, had negligible effects on the seedling heights (see Table 4) and any slight differences there were, were not significant ($p = 0.05$).

Very similar results were obtained from Inchnacardoch, Fleet, Wykeham and the Bush nurseries when the experiment was repeated in 1953 and 1954 using much heavier rollers, but only at Fleet were consistent height increases obtained from the main pre-sowing compaction treatments. In all cases, height differences between treatments were minute and of no practical value. Details are given in Table 33.

Effect of Compaction Treatments on the Total Yields of Seedlings

At Wykeham in 1952 the heavier pre-sowing compaction treatments increased the yields of seedlings at the end of the season by over ten per square foot (equivalent to approximately ten thousand plants per pound of Sitka spruce seed) when compared with uncompacted soil. Only small gains were obtained by firming the seed into the seedbed surface or by rolling in the grit cover after application. These small increases were shown to be not significant ($p = 0.05$) after statistical analysis. Tabulated data appear in Table 34, p. 119.

Mean Heights of Seedlings on Seedbeds subjected to different degrees of compaction. Wykeham Expt. 3/52 (DW)

Table 32

Treatment	Mean Heights in inches	
No compaction	0.64	S.E. ± 0.02
Compaction with 23 in. diam. roller of 1¼ cwts....	0.67	
" " " " " " 2¼ "	0.70	
" " " " " " 3¼ "	0.74	
Critical differences 5%	0.05	
1%	0.07	
No firming before covering....	0.69	S.E. ± 0.01
Firming before covering	0.68	Not significant
Unrolled after grit covering	0.69	S.E. ± 0.01
Rolled with 1¼ cwt. roller after grit covering	0.70	Not significant

In the 1953 experiments the results obtained at Wykeham in 1952 were confirmed only at Fleet. At Inchnacardoch the one-hundredweight roller increased the yield of seedlings, but the difference between it and the uncompacted treatments was not significant. Heavier compaction treatments, using the four and seven hundredweight rollers, produced slightly but not significantly lower yields. At Wykeham the uncompacted plots produced the greatest numbers of seedlings and increasing roller weights tended to lower the seedling yields.

Firming the seed into the bed surface had negligible effects on seedling yields at all three nurseries. Rolling the seed-covering media after application had no significant effects on seedling yields at Fleet or Inchnacardoch, but at Wykeham the treatment was definitely harmful. The grit used at Wykeham was Doncaster quartzite, a material of fairly large particle size in comparison with seedbed covers used at other centres. It appears that in this instance it was the combined effect of a coarse grit and a roller which materially assisted in the reduction of yields of the seedlings.

In 1954, confirmation of the 1952 Wykeham results was obtained at Inchnacardoch and the Bush. At Fleet the four and six hundredweight rollers increased the yield of seedlings, but the increase was not significant when compared with yields from uncompacted treatments. At Wykeham, increasing the weight of the roller caused a reduction in seedling numbers. The soil at Wykeham was extremely dry and fairly powdery at the time when compaction treatments were carried out, and in the heavier compaction treatments the roller tended to drag and skid rather than rotate. Under these circumstances it is likely that the net effect of the operation was to pulverise the soil, causing a breaking down of the natural crumb structure. After rain the soil would not have a very suitable structure for seed germination or growth.

Firming the seed into the bed surface, or rolling in the grit, did not significantly reduce the yield of seedlings at any of the nurseries. (See Table 35).

Table 33 *Seedling Mean Heights in the 1953 and 1954 Seedbed Compaction Experiments*

Treatment	Mean Heights in inches						
	1953			1954			
	Inchnacardoch	Fleet	Wykeham	Inchnacardoch	Fleet	Wykeham	Bush
No compaction	1.07	1.96	1.48	0.66	1.19	0.93	1.17
12 inch diam. 1 cwt. roller	1.05	2.14	1.44	0.68	1.28	0.92	1.26
„ „ „ 4 „ „	1.08	2.20	1.42	0.72	1.31	0.96	1.27
„ „ „ 7 „ „	1.20	2.18	1.36	0.70	1.47	0.98	1.29
S.E.	±0.05	±0.03	±0.04	±0.04	±0.04	±0.03	±0.03
Critical differences 5%	Not Sigt.	0.09	Not Sigt.	Not Sigt.	0.13	Not Sigt.	Not Sigt.
1%		0.12			0.17		
No firming before covering	1.14	2.08	1.47	0.71	1.31	0.94	1.26
Firming before covering	1.06	2.16	1.38	0.68	1.31	0.95	1.23
S.E.	±0.04	±0.03	±0.03	±0.03	±0.03	±0.02	±0.02
Critical differences 5% 1%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.
Unrolled after grit covering	1.08	2.12	1.44	0.67	1.31	0.91	1.22
Rolled with 1 cwt. roller after covering	1.11	2.12	1.42	0.72	1.32	0.98	1.27
S.E.	±0.04	±0.03	±0.03	±0.03	±0.03	±0.02	±0.02
Critical differences 5% 1%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.

Numbers of Seedlings on Seedbeds subjected to different degrees of compaction. Wykeham Expt. 3/52

Table 34

Treatments		Numbers of seedlings per square foot	
No compaction		59	S.E. ± 3
Compacting with 23 in. diam. roller of 1¼ cwts.		61	
„ „ „ „ „ „ 2¼ „		70	
„ „ „ „ „ „ 3¼ „		68	
Critical differences	5%	8	
	1%	11	
No firming before covering		62	S.E. ± 2
Firming before covering		66	Not significant
Unrolled after grit covering		62	S.E. ± 2
Rolled with 1¼ cwt. roller after grit covering		66	Not significant

Compaction Effects on Seedbeds Previously Treated with Bulky Organic Manures

It has been observed that the production of conifer seedlings is generally lower in seedbeds in which raw hopwaste or composts have been incorporated in late spring and shortly before seed sowing. The reduction in plant numbers has been frequently attributed to lack of consolidation before sowing, and remedial measures suggested to reduce these losses have been:

(a) To increase the degree of soil compaction by using heavier rollers than are at present available, or, by firming the seedbeds by foot tramping, or,

(b) by applying the hopwaste in winter, to permit consolidation by weathering and by encouraging earlier breakdown of some of the rawer organic materials.

Tramping by foot, although an excellent method for consolidation, and a proven satisfactory practice in many nurseries, is a laborious and costly procedure and one that is not always suitable. Winter applications of organic manures cannot be easily carried out in many cases, due to unsuitable ground conditions or because a crop of plants still occupies ground which has to be treated. Therefore, the use of a heavy roller is left as the most suitable alternative.

In order to confirm or disprove some of these theories, an experiment was carried out in 1955 at the Bush, Fleet and Wykeham and Inchnacardoch Heathland nurseries. This experiment had a 4 x 3 factorial design, and compared the effects on the growth and yield of Sitka spruce seedlings of no rolling, and of one, three and five hundredweight rollers on seedbeds to which (a) no hopwaste, and (b) hopwaste at 1,000 lb. per 100 sq. yds., had been incorporated, either on the date or sowing, or applied in early winter.

The 1955 growing season was much drier than normal at all centres, and was therefore a season in which one would normally expect pronounced differences in numbers of seedlings between compaction treatments.

Table 35 *Seedling Numbers in the 1953 and 1954 Seedbed Compaction Experiment*

Treatment	Numbers of Seedlings per Square Foot						
	1953			1954			
	Inchnacardoch	Fleet	Wykeham	Inchnacardoch	Fleet	Wykeham	Bush
No compaction	84	96	125	139	150	192	102
12 inch diam. 1 cwt. roller	93	108	132	148	149	182	110
,, ,, ,, 4 ,, ,,	79	109	118	157	152	177	111
,, ,, ,, 7 ,, ,,	75	101	116	150	156	169	126
S.E.	S.E. ±5	S.E. ±3	S.E. ±6	S.E. ±4	S.E. ±5	S.E. ±5	S.E. ±6
Critical differences 5% / 1%	Not Sigt.	10 Not Sigt.	Not Sigt.	10 Not Sigt.	Not Sigt.	15 Not Sgt.	17 Not Sgt.
No firming before covering	83	104	123	148	152	176	109
Firming before covering	83	104	118	150	153	184	115
S.E.	S.E. ±3	S.E. ±2	S.E. ±4	S.E. ±2	S.E. ±4	S.E. ±4	S.E. ±4
Critical differences 5% .... / 1%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.
Unrolled after grit covering	82	101	128	149	151	181	114
Rolled with 1 cwt. roller after covering	83	106	113	150	153	179	113
S.E.	S.E. ±3	S.E. ±2	S.E. ±4	S.E. ±2	S.E. ±4	S.E. ± 3.6	S.E. ±4
Critical differences 5% .... / 1%	Not Sigt.	Not Sigt.	12 Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.

Results of the Experiment (see Table 36)

All three compaction treatments at Fleet produced a highly significant height increase in seedlings when compared with the control, but at the remaining three nurseries none of the compaction treatments significantly affected the height growth of the seedlings.

Effects of Treatments on Seedling Yields

Only at the Bush nursery were there any appreciable or significant differences in seedling yields between the various compaction treatments. At this nursery all three compaction treatments significantly increased the yields of seedlings in comparison with uncompacted seedbeds. Differences between individual compaction treatments were, although appreciable, not significant. In addition, spring applications of hopwaste led to much lower yields of seedlings in comparison with the winter applications, and the plots which received no hopwaste. Winter application also significantly increased the yield of seedlings in comparison with plots which received no hopwaste.

At Fleet, Inchnacardoch and Wykeham nurseries neither the compaction nor hopwaste applications had any significant effect on seedling yields. There were, however, consistent indications at all centres that compaction by one or three hundredweight rollers increase the final yield of seedlings, and that rollers weighing more than three hundredweights produce slightly, but consistently, lower yields than the three hundredweight treatments.

Discussion

From these experiments it has been shown that in the majority of nurseries, compaction of seedbeds provides a stimulus to earlier germination of seed. Because of this it would be expected that earlier germination would result in a taller crop of seedlings, due to the fact that the seedlings which germinated early had the benefit of a longer growing season. This was not proved to be the case, and in most experiments differences in the mean heights of seedlings growing on seedbeds compacted by rollers of different weights were generally not significant. In the few instances where differences were shown to be statistically significant, the differences were of no great practical importance.

The effects of compaction of seedbeds, before sowing, on the yield of seedlings, was consistent. In nine experiments out of eleven, beds which had been compacted with a one hundredweight roller showed an increase in the number of seedlings per square foot, ranging from two to twelve plants (average 7 per square foot, or approximately seven thousand plants per pound of seed). At eight out of eleven nurseries, beds rolled with a three or four hundredweight roller produced increases ranging from two to eighteen plants per square foot (average ten per square foot or approximately ten thousand per pound of seed sown). Compacting seedbeds with a seven or five hundredweight roller produced fewer seedlings than beds compacted with a four or three hundredweight roller at nine out of eleven nurseries. This suggests that over-compaction is possible, and that heavy rollers can be harmful.

The data on total numbers was quite precise, but even so the increases recorded were rarely shown to be significant, since differences necessary for significance at even the 5 per cent level were quite high. This was due, in part, to the design of the experiment, and it is fairly certain that simpler experiments comparing, say three treatments, e.g. no compaction, compaction with a one hundredweight roller, or compaction with a four hundredweight roller, replicated more times, would confirm that the increases recorded are significant and not due to chance.

The Effect on Mean Heights and Numbers of Sitka Spruce Seedlings of Compaction and Hopwaste Treatments Seedbeds

Table 36

Treatment	Mean Heights inches				Numbers per Square Foot			
	Bush	Fleet	Inchnacardoch	Wykeham	Bush	Fleet	Inchnacardoch	Wykeham
Uncompacted seedbeds	1.91	1.67	1.61	1.35	83	86	74	85
Beds compacted with 1 cwt. roller	2.05 S.E. ± 0.07	1.97 S.E. ± 0.04	1.64 S.E. ± 0.07	1.34 S.E. ± 0.02	92 S.E. ±3	90 S.E. ±4	82 S.E. ±3	90 S.E. ±4
Beds compacted with 3 cwt. roller	1.93	2.00	1.59	1.42	97	95	79	94
Beds compacted with 5 cwt.	2.00	2.01	1.63	1.40	95	86	76	88
Critical differences: 5%	Not	0.13	Not	Not	9	Not	Not	Not
1%	Sigt.	0.18	Sigt.	Sigt.	Not Sigt.	Sigt.	Sigt.	Sigt.
No hopwaste	1.98	1.8	1.55	1.13	93	88	83	88
Hopwaste applied in spring	1.86 S.E. ± 0.05	2.07 S.E. ± 0.04	1.70 S.E. ± 0.06	1.54 S.E. ± 0.02	84 S.E. ±3	91 S.E. ±2	79 S.E. ±3	90 S.E. ±3
Hopwaste applied in winter	2.07	2.03	1.61	1.46	98	91	79	91
Critical differences: 5%	Not	0.13	Not	0.06	8	Not	Not	Not
1%	Sigt.	0.18	Sigt.	0.08	10	Sigt.	Sigt.	Sigt.

The experiments demonstrated that firming the seed into the seedbed surface after sowing has little or no effect on either the height growth or final yield of seedlings.

Rolling in the covering grit with a one hundredweight roller has generally no effect on heights or numbers, but when a coarse grit is used the practice can be harmful and may cause reductions in final yields.

Heavy rolling of seedbeds to which hopwaste had been applied at rates of 1,000 lb. per 100 square yards did not, in general, produce the expected increase in seedlings numbers when compared with uncompacted beds. Compaction increased the yields slightly but not significantly. Furthermore, applying hopwaste to seedbeds in winter did not produce greater yields of seedlings than hopwaste applications made in spring.

Conclusions

The experiments have given very strong indications that compacting seedbeds *before* sowing with a twelve inch diameter roller weighing approximately two hundredweights is the most satisfactory method and gives maximum production of seedlings. Compaction speeds up the rate of germination, but does not greatly affect the final height growth of seedlings. Slightly firming seed into the seedbed surface, and rolling the seedbeds after applying grit covers have little effect on the growth and yield of seedlings. Applications of hopwaste to seedbeds in winter are not likely to produce higher yields of seedlings than spring applications. Compaction of hopwaste treated seedbeds with rollers weighing from one to five hundredweights showed that in general the heavier rollers give no greater benefits than the lighter rollers as far as height growth or yields are concerned.

THE STORAGE OF ONE-YEAR CONIFER SEEDLINGS

By R. FAULKNER

232.324.9

THE AREA OF SCOTTISH HEATHLAND and woodland nurseries has steadily risen since 1945. As a result, problems of management have also increased, mainly on account of the tremendous task of lifting, packing and despatching seedlings during a comparatively short period of time in the late winter and spring.

The heathland or ex-woodland nurseries are located either on the upland heaths or in small felled pinewood areas on old heathland sites, and are usually isolated in districts where seasonal labour is difficult to obtain. They are used almost entirely for the production of large one-year coniferous seedlings which can be raised at very low cost. After lifting the plants are taken to the larger 'established' type of nursery for lining-out for the production of forest planting stock. Lining-out in established nurseries is mainly confined to the spring months, and because of this demands for plants from the heathland nurseries are heaviest during the early and middle spring months.

In order to spread the load of lifting and grading seedlings over as wide a period as possible, it was suggested that various methods of storing autumn- and winter-lifted seedlings should be tried experimentally in order to find a satisfactory technique. For this reason three experiments on the problem were carried out from 1953 to 1955 in the Teindland nurseries in Morayshire with the help of Conservator, East Scotland, and his staff.

1953 Experimental Treatments

The experimental treatments used were those which were considered practical and inexpensive, and which could be used on a larger scale. In the first experiment, in 1953, one-year seedlings of lodgepole pine, Japanese larch and Sitka spruce were lifted at monthly intervals from November to March, and stored by several different methods as listed below:

(1) Seedlings *not* bundled, stored in boxes in the forest with no cover above.
(2) Seedlings *not* bundled, stored in boxes in the forest with a roofing felt cover placed above the seedlings.
(3) Seedlings *not* bundled, stored in boxes in a well-ventilated shed.
(4) Seedlings tied in bundles of 100 plants, and stored in boxes in the forest with a felt cover above.
(5) Seedlings *not* bundled, sheughed, (="heeled in") in thin lines in the nursery of origin.
(6) Seedlings tied in bundles of 100 plants and sheughed in the nursery of origin.
(7) Seedlings *not* bundled, sheughed on the forest floor and with the sides surrounded by moss.
(8) Seedlings bundled and sheughed on the forest floor of a twenty-foot tall Scots pine plantation with the sides surrounded by moss.

The experimental design was a 5 (months) x 8 (methods of storage) factorial. Treatments were replicated in five blocks both when in storage and when lined-out.

In April the plants were transported to Newton nursery and a sample of 100 plants was lined-out in each block immediately on receipt. At the time of lining-out, some plants were lifted from the Teindland seedbeds and lined-out on the same day, at Newton. This provided a demonstration of the treatment that is normally considered best.

In the original experiment a test of bundled and unbundled plants stored in a local salmon ice-house was also included. Unfortunately, sea-water swept into the house during the Great Gale of January 31st, 1953, and soaked some of the earlier storage treatments with brackish water. These plants were salvaged and later lined-out in demonstration plots alongside the main experiment.

1953 Experimental Results

The experiment was assessed in November on the basis of survival of the transplanted seedlings after one growing season in the transplant lines. The data obtained (see Table 37) clearly showed for all three species that unbundled or bundled plants, when stored in boxes in the forest with a felt cover above, and, unbundled plants when boxed and stored in the ventilated wooden shed, were generally least successful, irrespective of the month of lifting.

The most successful storage treatments for all three species were those in which bundled and unbundled plants were sheughed in the nursery of origin, or kept in sheughs made of moss under the cover of a young pinewood.

Storage in the forest in uncovered boxes gave quite satisfactory results with Sitka spruce when lifted and stored *before* March, but not during March. Japanese larch lifted in January or February gave good results with this method, but at other times the method was not satisfactory. Lodgepole pine gave the highest survival percentage figure (81 per cent) when lifted and stored by this method in January; at other times the method was not satisfactory for this species.

When comparing the months of storage, combined with most satisfactory methods of storage, it is clear that the most suitable months for storing lodgepole pine were January to March inclusive; February and March for Japanese larch, and November to March for Sitka spruce.

Data from the demonstration plots of bundled and unbundled seedlings stored in boxes in the ice-house, and of plants lifted and lined-out on the same day, indicate that the effects of the brackish water on plants put into store before February were not great. Overall, the ice-house storage treatment gave reasonably satisfactory results, and except for the March storage of Japanese larch, bundled plants of all species compared favourably with plants lifted and lined-out on the same day.

1954 and 1955 Experiments

The obviously unsuccessful treatments of 1953 were discarded when preparing the 1954 and 1955 plans, and a new experimental design was used. This was a 2 x 4 x 5 factorial design, to compare the effects of storing one-year seedlings of lodgepole pine, Japanese larch and Sitka spruce by measuring the subsequent growth and survival after lining-out in April. The treatments were-

(1) Bundled into hundred-plant bundles.
(2) Packed or sheughed without bundling.
} 2

Seedlings treated as above then stored:

(a) In uncovered wooden boxes in the forest (each box holding 5,000 plants)
(b) Sheughed in thin lines in the nursery.
(c) Placed upright on the forest floor with roots given side protection of moss*
(d) Stored in wooden boxes in salmon ice-house.
} 4

Work as specified above carried out in the following months:

(i) Lifted and stored in November.
(ii) Lifted and stored in December.
(iii) Lifted and stored in January.
(iv) Lifted and stored in February.
(v) Lifted and stored in March.
} 5

* This treatment was omitted for lodgepole pine and Japanese larch in 1954.

1954 and 1955 Experimental Results

The experiments in 1954 were assessed on the basis of the percentage and mean heights of usable plants, and the percentage survival rate. An assessment of usable plants, i.e. plants which had retained twenty-five per cent or more of the foliage, was carried out because a proportion of the plants were looking unhealthy and blasted in appearance. This was particularly noticeable on the lodgepole pine. "Living" or "surviving" plants were plants which showed any signs of life at all. In 1955, as in 1953, the proportion of unusable plants was extremely low, and a special assessment of usability was not carried out.

MEAN HEIGHTS. Data for mean heights are not presented in Table 38 for either year on account of the very small differences between treatments. Although differences between treatments were statistically significant in a few isolated cases, they were in the order of 0.3 of an inch or less and are not of any practical value.

PERCENTAGE OF USABLES IN 1954. In Table 38 the "percentage usable" data have been transformed, by angular transformation of percentages to degrees, for statistical analysis purposes. From the analysis it is evident that bundling lodgepole pine or Sitka spruce seedlings during storage produced slight, but significantly, more usable transplants than did treatment without such bundling. With Japanese larch bundling had no appreciable adverse or beneficial effects.

Of the three methods of storing lodgepole pine, and the four methods of storing Japanese larch and Sitka spruce seedlings, storage in boxes in the forest resulted in significantly lower yields of usable transplants, when compared with storage in nursery or forest sheughs, or in the ice-house. Differences in the production of usable seedlings between the nursery sheugh and the ice-house treatments were not significant.

The month of lifting and storing plants did not significantly affect the out-turn of usable Japanese larch transplants; but for lodgepole pine, November, December and March were much less satisfactory periods for lifting and storing than were January or February. For Sitka spruce, November and March were the least suitable months, January being the optimum.

Plants from all the storage treatments compared very favourably with the demonstration plants which were lifted and lined out on the same day, but the demonstration of plants lifted and lined out in March gave considerably higher yields of "usables" than methods whereby plants were lifted and put into storage. This strongly suggests that had the period of storage been limited to March, the storage treatments would have given even higher survival and usable percentage figures.

PERCENTAGE SURVIVALS IN 1955. Bundling larch or spruce seedlings did not affect the survival rate of the transplants produced after lining-out, but the data gave a strong indication that bundling lodgepole pine was advantageous.

There were only slight survival differences between the four storage treatments for all three species. In the lodgepole pine and Japanese larch sections of the experiment, the month of lifting and storing had little effect on the percentage of survivals; but in the Sitka spruce section the November storage treatments gave significantly lower yields of survivors than those methods in which the plants were lifted and stored in subsequent months.

Comparisons between Lodgepole pine, Japanese larch and Sitka spruce on their Suitability for Storage

When making broad comparisons between species over all three years, it is quite clear that, of the three species under test, Sitka spruce was consistently the 'hardiest' plant in storage during the winter and spring periods, and gave the highest survival figures when lined out in early April. Lodgepole pine was second on the list, having given higher survival figures than Japanese larch in two out of three years. Japanese larch takes third place. Had lining-out been carried out a month earlier, it is most likely that even higher percentage survival figures would have been recorded for all three species, and in particular for larch, which is the earliest tree to flush its needles in spring.

Discussion

From this series of experiments it has been shown that satisfactory storage of one-year seedlings, lifted during the period from November to March, is possible under certain conditions and providing the plants are lined-out during April. As evidenced by the 1954 data, earlier lining-out of stored plants would possibly result in even higher survival. Generally, plants which were lifted and stored in March were not as successful as plants lifted in mid-winter—a fact which is in all probability due to the extensive disturbance and partial loss of root systems after early root growth has started. Furthermore, it was noticed that the soil surrounding the plant rootlets was much drier in March, and was therefore lost in greater quantity on lifting then than at other times. The lack of soil may have been partially responsible for the slightly poorer figures for plants lifted and stored in March.

Japanese larch was not quite as successful when lifted and put into storage in the earlier months. It is thought that this may be due to the fact that one-year seedlings lifted in early winter still carry a fairly large proportion of dead needles. When packed and put into storage the dead needles hold moisture and produce favourable conditions for fungi, which in turn may have an adverse effect on the plants themselves.

Disease-free plants were used throughout the experiments. It is important that plants infected by fungi, and in particular by *Botrytis*, should not be stored. Experience in other nurseries has shown that such plants infect adjacent healthy plants and may cause extensive damage.

Conclusions

The most satisfactory ways of storing one-year conifer seedlings lifted during the period November to March is by carefully sheughing them in the nursery of origin. Storage by placing the seedlings on a woodland floor and surrounding the roots by damp moss, or, storing the seedlings in boxes in a cool building is also satisfactory. Storage in boxes under a forest cover gives reasonably good results also. Unsuitable treatments are storage of seedlings in boxes in uncooled, well-ventilated sheds, and storage in boxes with felt cover protection immediately above the plants.

Bundles of one hundred seedlings store equally well and sometimes slightly better than seedlings which are unbundled but packed tightly during storage.

It is recommended that Sitka spruce should be lifted and placed into nursery sheughs first, starting in late November or December. The spruces should be followed by the pines. Larches can be lifted and stored in nursery sheughs during December, January and February, but because this species is the first to flush it should be given priority for lining-out in late February and early March. If for unforeseen circumstances it is not possible to move larch before the end of February, it is probably best to leave the plants *in situ* and only lift them immediately before shipment.

Larger-scale trials in other Scottish nurseries have broadly confirmed these results.

From experiences at other nurseries it has proved disastrous to store frost-damaged seedlings or seedlings infected by fungi. Such plants infect healthy plants alongside.

Table 37

Percentage Survival of Lodgepole pine, Japanese larch and Sitka spruce seedlings, lifted during winter and spring months and stored under various conditions, after lining-out in Newton Nursery in 1953

Treatment	November			December			January			February			March			Mean		
	P.C.	J.L.	S.S.	P.C.	J.L.	S.S.	P.C.	J.L.	S.S.	P.C.	J.L.	S.S.	P.C.	J.L.	S.S.	P.C.	J.L.	S.S.
(1) Not bundled, in boxes, no cover, in forest	74	60	88	72	73	95	81	84	88	75	80	90	38	10	23	68	61	77
(2) Not bundled, in boxes, felt cover, in forest	0	1	3	13	41	2	24	46	35	52	46	50	58	6	45	29	28	27
(3) Not bundled, in boxes in ventilated shed	0	0	0	5	0	0	25	0	0	0	0	6	4	0	4	7	0	2
(4) Bundled, in boxes, with felt cover, in forest	0	0	0	0	16	6	31	54	58	45	41	74	54	12	38	26	25	35
(5) Not bundled, thin sheughs, in nursery	81	85	88	83	89	96	85	79	95	82	81	95	90	80	96	84	83	94
(6) Bundled, thin sheughs, in nursery	78	72	94	80	76	94	84	89	95	88	79	91	93	86	94	85	80	94
(7) Not bundled, sheughed, in forest	85	59	89	67	77	96	80	68	90	88	84	94	84	84	85	81	74	91
(8) Bundled, sheughed, in forest	80	57	94	86	79	94	86	83	96	89	82	94	87	80	92	86	76	94
Mean	50	42	57	51	56	60	62	63	70	65	62	74	64	45	60	58	54	64
Demonstration																		
Not bundled, in boxes, ice house	67	64	92	65	78	92	62	69	92	68	65	92	56	28	89	63	59	91
Bundled, in boxes, ice house	66	65	96	77	77	93	82	68	93	78	74	93	64	21	90	73	61	93
Lifted and lined out on same day	P. contorta = 77%						Japanese larch = 56%						Sitka spruce = 96%					

Notes: P.C. = Lodgepole pine. J.L. = Japanese larch. S.S. = Sitka spruce.

Statistical Analysis of Data from Table 37

Table 37a

	Lodgepole pine		Japanese Larch		Sitka Spruce	
	Months of lifting	Storage Method	Months of lifting	Storage Method	Months of lifting	Storage Method
Standard Error ±	2.01***	2.5***	1.6***	2.0***	1.7***	2.2***
Critical difference 5%	5.6	7.0	4.5	5.7	4.7	6.0
1%	7.3	9.3	6.0	7.5	6.2	7.9
0.1%	9.3	11.8	7.6	9.6	7.9	10.0

*** Very highly significant p = 0.01

Table 38

1954 Percentage Usable data, 1954 and 1955 Percentage Survival Data of Lodgepole pine, Japanese larch and Sitka spruce seedlings, lifted during winter and spring months and stored under various conditions, after lining-out in Newton Nursery.

Storage Treatments	Lodgepole pine				Japanese larch				Sitka spruce				
	1954			1955	1954			1955	1954			1955	
	Percentage usable		Percentage survival	Percentage survival	Percentage usable		Percentage survival	Percentage survival	Percentage usable		Percentage survival	Percentage survival	
		T.D.				T.D.				T.D.			T.D.
Bundled	41	40	61	88	86	68	89	78	84	66	91	92	—
Unbundled	33	35	56	85	83	65	88	79	78	62	87	92	—
Standard Error ±	—	1*	—	Not analysed	—	1.2	—	Not analysed	—	1.1**	—	Not analysed	
Critical difference 5%	—	4	—		—	Not	—		—	3.0	—		
1%	—	—	—		—	sig.	—		—	4.0	—		
Method of Storage													
In boxes in forest, no cover	29	33	51	86	76	61	82	81	74	59	83	93	—
Sheughed in nursery in thin line	39	38	63	88	88	69	90	79	83	65	93	92	—
On Forest floor, roots protected moss†	—	—	—	85	89	70	92	78	—	—	—	94	—
In boxes in ice-house	43	41	62	86	84	67	90	77	86	68	90	93	—
Standard Error ±	—	1.8**	—	Not analysed	—	1.6**	—	Not analysed	—	1.3**	—	Not analysed	
Critical difference 5%	—	5.0	—		—	4.6	—		—	3.7	—		
1%	—	6.7	—		—	6.1	—		—	4.9	—		

Table 38—continued.

Storage Treatments	Lodgepole pine				Japanese larch				Sitka spruce				
	1954			1955	1954			1955	1954			1955	
	Percentage usable		Percentage survival	Percentage survival	Percentage usable		Percentage survival	Percentage survival	Percentage usable		Percentage survival	Percentage survival	
		T.D.				T.D.				T.D.			T.D.
Months of lifting													
November	35	36	55	84	88	70	93	77	60	51	74	86	68
December	32	34	48	86	86	68	89	77	84	67	94	93	77
January	46	42	68	86	80	66	88	81	91	73	95	94	76
February	46	43	69	88	88	70	94	79	87	69	94	94	76
March	27	31	51	88	76	61	79	81	78	62	88	93	75
Standard Error ±	—	2.3**	—		—	1.8	—		—	1.7**	—	—	0.6**
Critical differences 5%	—	6.5	—	Not analysed	—	Not sig.	—	Not analysed	—	4.8	—	—	2.1
1%	—	8.6	—		—		—		—	6.3	—	—	2.8
Demonstration													
Plants lifted and lined-out March	58	50	—	—	100	90	—	—	88	70	—	—	—
Plants lifted and lined-out April	25	30	—	88	83	66	—	86	66	55	—	94	—

Notes: † This treatment was not carried out for lodgepole pine and Sitka spruce in 1954.

T.D. = Transformed data.

*=Significant, p=0.5. ** = Highly significant, p = 0.1

MANURING OF CONIFER SEEDLINGS DIRECTLY PLANTED IN THE FOREST

By R. G. GREEN and R. F. WOOD

237.4

DURING the season of 1950 very considerable numbers of seedlings (both one-year and two-year) of several coniferous species were planted throughout the country. Previous experience in the use of conifer seedlings had shown that, while it was quite possible to obtain satisfactory results on suitable sites and in favourable seasons, the hazards in large-scale afforestation were too high and outweighed the nursery economies. However, some resurgence of interest in seedlings for forest planting had resulted from the improvements in nursery performance which were becoming apparent during this period; the large seedlings obtained in the new heathland nurseries especially suggested the possibility of dispensing with the transplant stage. The late Dr. E. M. Crowther had achieved considerable success in establishing seedlings of Sitka spruce and Scots pine on a number of forest sites (many by no means favourable) and besides demonstrating the importance of adequate nutrition in the nursery his experiments had included many instances where performance in the forest was greatly enhanced by further manuring at the time of planting.

Table 39

Distribution of Trials by Conservancy and Species

Conservancy	Douglas fir	European larch	Japanese larch	Corsican pine	Scots pine	Sitka spruce	Tsuga heterophylla	Norway spruce	Pinus contorta	Total
North Wales			11	2		1				14
South Wales			11							11
North West England			8							8
South West England				4						4
North East England			6	1						7
South Scotland			17			10		2		29
North Scotland	1	6	18		10	9	1		8	53
East Scotland			3			1			2	6
West Scotland		1	17			23			11	52
Total:	1	7	91	7	10	44	1	2	21	184

In the light of such and other experiences the then Deputy Director General (Mr. W. H. Guillebaud) decided to conduct an extensive trial of manuring of seedlings in the forest. An instruction to all Conservators (State Forest Memorandum 2, 11/4/50) called for simple replicated experiments to be superimposed on plantations of seedlings of the current season, comparing "strips of twelve rows of (manured) plants alternating with unmanured control strips six rows in width—". In practice, many of the layouts adopted differed substantially from what had been intended, and a considerable number of the experiments were not adequately replicated or controlled. Some 184 such experiments in all were attempted, the distribution being as shown in Table 39.

It will be noted that all but one of the Sitka spruce and all the *Pinus contorta* trials were in Scotland.

Survival of Seedlings

This series of trials did not permit any critical comparison of the behaviour of seedlings versus transplants, nor were detailed assessments of survival attempted at the end of the first season. Foresters were, however, asked to report the percentage of "beating up" required in the individual trials during the two subsequent seasons. It is clear that the results were on the whole very poor.

Of the species most commonly represented, Japanese larch, only a third of the trials required *less than* 25 per cent replacements. Sitka spruce fared rather better, three-quarters of the trials falling below this figure, and other species were intermediate in performance. Comparisons of one-year and two-year seedlings on a country-wide basis might have yielded some information, but in fact failures and successes appear quite fortuitously distributed between them.

Manuring

The manures and dosages applied were prescribed by the late Dr. E. M. Crowther of the Rothamsted Experimental Station.

(a) For moorland and heathland sites, 2 oz. of a complete fertiliser (5 % N. 10% P_2O_5. 5% K_2O, Fison's No. 8); and

(b) For sites with much grass the nitrogen was omitted (to avoid stimulation of the grass) and 1½ oz. of potassic superphosphate (15% P_2O_5, 8% K_2O, Fison's No. 7) were used.

In a few cases where the general practice was to manure with ground mineral phosphate (27% P_2O_5 approx.) at 1½ oz. per plant, this treatment was included in trials as an extra comparison.

The fertilisers were applied during the period May-July 1950. Special measures were provided for the purpose, and the fertilisers were placed in bands or notches on two sides of the plants, some six inches or so away from the collar.

Response to Manuring

Field officers were asked to report on the trials at the end of the first season—scoring for the apparent effects of the fertilisers by the descriptions "very effective, effective, ineffective, harmful". A summary of these reports by species is given in Table 40, p. 134.

It should be noted that the total of all the "effective" observations (Columns (1), (2) and (3)) was 41, compared with a total of 162 for "ineffective" observations.

It is probable that a higher proportion of "effectives" would have been recorded at the end of the second growing season. (A number of trials scored as 'ineffective' did in fact develop quite sizeable effects later on.) But at the time of assessment, observers would have little but colour differences to go by.

Effectiveness of Manuring

Table 40

Species	Very Effective	Effective	Slightly Effective	Ineffective	Harmful	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Japanese larch	2	12	1	93	0	108
Sitka spruce	0	15	2	28	0	45
Pinus contorta	3	4	0	14	0	21
Corsican pine	0	0	0	8	0	8
Scots pine	0	1	0	9	0	10
Douglas fir	0	0	0	1	0	1
European larch	0	1	0	6	0	7
Norway spruce	0	0	0	2	0	2
Tsuga heterophylla	0	0	0	1	0	1
Total	5	33	3	162	—	203

Certain trials extended to more than one (adjacent) comts. and separate observations were recorded for compartments. Hence this total is larger than that in Table 39.

Of some interest is the absence of reports of damage due to these fertilisers, and that nothing of this sort was apparent in such a large number of trials is very useful confirmation of the recent experience with highly soluble forms of phosphate. Past experience was less fortunate (Zehetmayr, 1954).

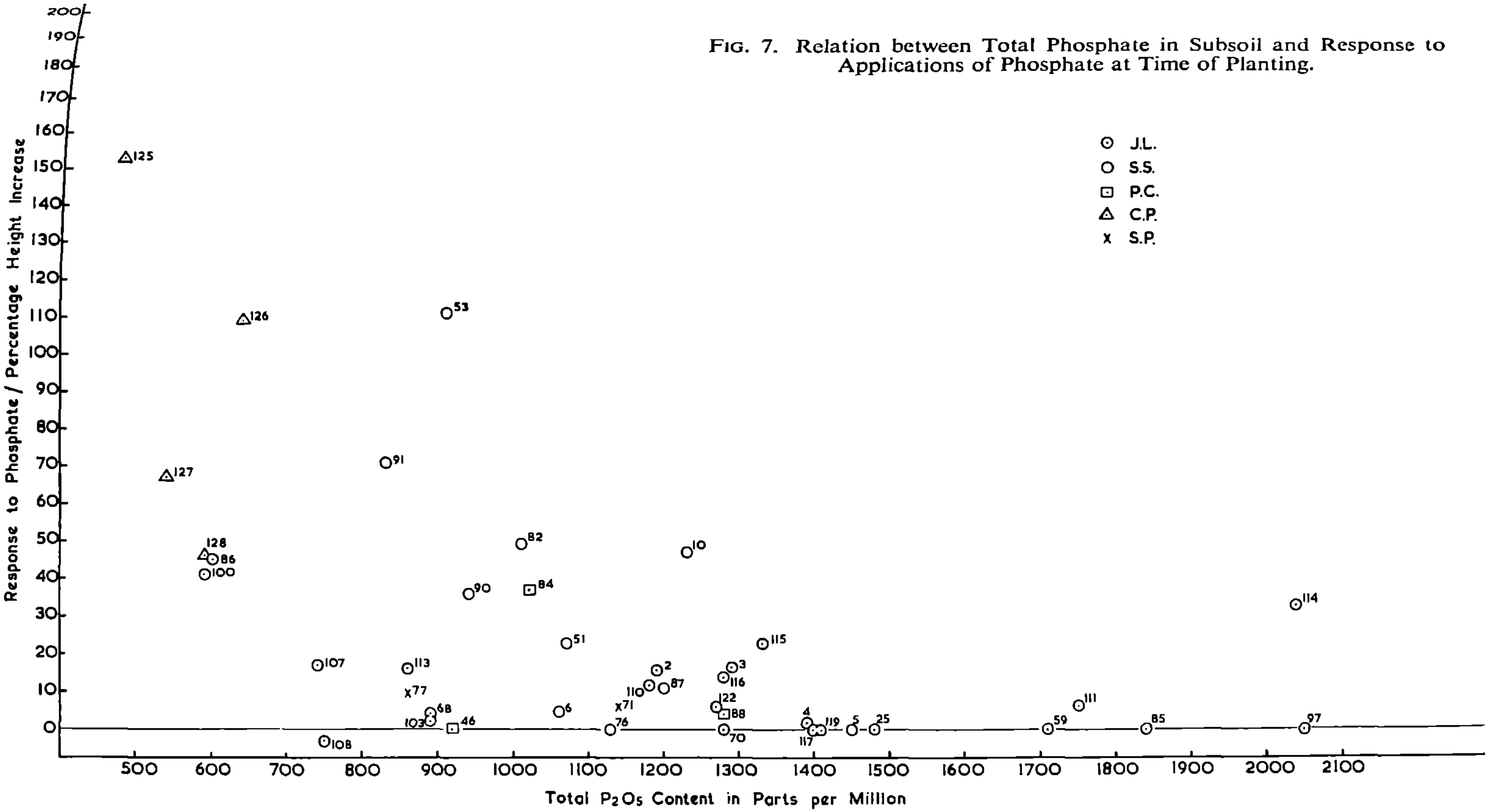
On the other hand, there was no suggestion of improvement in the initial survival rate due to manuring. This is in accord with general experimental evidence. In several instances (see Table 41) manuring proved critical for the establishment of crops on particularly poor sites, unmanured trees being moribund or actually dead after four or five seasons.

In 1955, it was decided to assess a number of the trials in order to obtain any information available on the relationship between site, species and response to fertilisers. Forty-five of the trials were selected, on the criteria of high degree of survival of the original seedlings, and of adequate experimental layout.

The height of the plants was measured to the limit of the 1954 season's growth (since a number of the assessments were carried out during the 1955 growing season). The means are recorded in Table 41. A somewhat generalised description of the vegetation was made; and soil samples were collected, four to each plot, from the C horizon if apparent, or if not, from the level to which root penetration could be expected to reach.

At the suggestion of Dr. Leyton of the Imperial Forestry Institute, Oxford, the samples were analysed by Dr. W. H. Hinson at Alice Holt to obtain an estimate of total phosphate (on the lines of the carbonate fusion method of Muir (1952)), and the values obtained are recorded in Table 41, together with the

FIG. 7. Relation between Total Phosphate in Subsoil and Response to Applications of Phosphate at Time of Planting.



measurement data for the trials. It will be noted that no estimates of total phosphate have been made for the peat soils encountered, since it is not felt that such figures on a weight basis are likely to afford useful comparisons with those of the mineral soils.

Response to fertiliser treatment has been plotted against total phosphate content of the "subsoil" (Fig. 7). Percentage height increase has been adopted as a measure of the response, since the data include several species and considerable differences in height growth according to the quality of the site. (It is not of course a useful measure in the few cases where control plots have virtually failed.) No attempt has been made to fit a curve, not would it be justifiable; the figure should be regarded simply as a pictorial representation of the data, which may afford useful suggestions for the direction of future work.

Discussion

The trials for which measurements are available are not a "sample" of the sites occupied by any species, although they can be regarded as a more or less fortuitous selection. There is little point, therefore, in commenting at any length on the levels of phosphate represented in any region or class of soils. Note should be taken, however, of the specially low values obtained on the Bagshot beds at Wareham and Purbeck, and the rather low figures for the trial areas at Allerston Forest on the East Yorkshire moors; these are two general areas where phosphate responses are classical features of our earlier experiments.

There is a fairly strong suggestion that responses to phosphate are confined to soils which fall below some threshold value for this nutrient, perhaps on this estimate in the neighbourhood of 1,300 parts per million for Sitka spruce. Also the response appears to increase as the level of phosphate falls.

Although this is the kind of result one might expect to find, determinations of soil phosphate have seldom shown much relationship to phosphate manurial responses. Analyses have usually been made for 'available' (readily extractable) phosphorus in the upper part of the profile; and it was assumed from the literature, that this approach would not be profitable. The work of Stoate (1951) in Australia and Van Goor (1954) in the Netherlands does suggest that total phosphate may be a useful guide to site quality in certain circumstances though the levels with which these workers were concerned appear markedly lower than those of which we have experience.

This investigation only gives some guidance on the conditions under which an initial response to phosphorus is obtained, and Leyton (1954) has suggested that such early responses do not necessarily mean that phosphorus will be the important limiting element later on. Hence variations in total phosphate of this order might not have much bearing on ultimate yield. This requires to be investigated.

In the meanwhile, a practical question is whether field officers can be given any better guidance for the application of phosphate than they already possess? As has already been mentioned, the number of sites sampled is quite inadequate for any generalisations about the phosphate status of broad types. But at least it can be said that there have been few surprises, and the sort of evaluation we are accustomed to make on the basis of vegetation is supported by this evidence. There is certainly no suggestion that the use of phosphate ought to be extended to any important type of ground on which it is now wholly unconsidered. However, this extra information ought to make us aware that we have sites which fall further below the common levels of fertility (in respect of this element at least) than perhaps we suspect, and on these we should manure all species whether we have been in the habit of considering them demanding or otherwise.

It will be noted that responses in this series of trials have been ascribed throughout (somewhat uncritically) to phosphorus. The justification rests on the few comparisons available between P.K. or N.P.K. manures and ground mineral phosphate, which do not suggest any important response to the other nutrients, and on much other experimental evidence outside this series.

There is little that can be said on this evidence concerning the relative responses of the various species. Of the two that were examined in a number of experiments, Japanese larch appears to respond to some degree over a wider range of soil phosphate, but the phosphate never increased the height by more than about 50%. Sitka spruce on the other hand showed a very much greater response at low levels of phosphate but little or no response where the soil phosphate exceeded 1,300 parts per million.

Summary

(1) Extensive trials of seedlings (manured and unmanured) carried out in 1950, exhibited generally poor survival; Japanese larch being less satisfactory in this respect than Sitka spruce.

(2) Early visual assessments did not suggest much advantage from fertilisers (P., P.K. or N.P.K.) on initial survival. But no reports of damage from the use of soluble forms of phosphate were received. On certain poor sites, manuring proved critical for establishment.

(3) Approximately a fifth of the trials showed some response to fertilisers by the end of the first season.

(4) A selection of the trials were measured at the end of the fourth growing season, soil samples from the subsoil were analysed for total phosphate.

(5) A fairly strong suggestion of a "threshold value" of some 1,300 parts per million of phosphate in the subsoil was obtained; below this, responses to phosphate added at the time of planting may be expected for Sitka spruce. There is some suggestion that Japanese larch will respond appreciably only when the value is somewhat lower.

REFERENCES

L. Leyton (1954) — *The Growth and Mineral Nutrition of Spruce and Pine in Heathland Plantations.* Imp. For. Inst. Oxford Inst. Paper. No. 31.

J. W. Muir (1952) — The Determination of Total Phosphorus in Soil, *The Analyst* Vol. 77. No. 915.

J. W. L. Zehetmayr (1954) — *Experiments in Tree Planting on Peat.* Bulletin No. 22 Forestry Commission. H.M.S.O. London.

T. N. Stoate (1951) — *Nutrition of the Pine.* Commonwealth Forestry and Timber Bureau, Bulletin 30.

C. P. van Goor (1954).... Growth and Site of Japanese Larch in the Netherlands, *Nederlandsch. Boschbouw Tijdschrift*, 26 (11).

Assessment of Manuring Effects, Growth Response, and Phosphate Content of the Soil

Table 41

Plot No.	Species	Forest	Manured Height Ft.	Control Height Ft.	Difference Ft.	Diff. req. for 5% sig. Ft.	% Height Increase	Growth Response	P_2O_5 Contents %
87	Sitka spruce	Deer	2.02	1.82	.20	.23	11	Slight	.120
53	,,	Asknish	2.74	1.30	1.44	1.07	111	Good	.091
52	,,	,,	2.53	.99	1.54	.25	156	Very good	
51	,,	,,	2.49	2.03	.46	.44	23	Slight	.107
63	,,	Inverinan	1.52	.922	.60	.43	64	Good	
10	,,	Cairn Edward	1.9 G.M.P.2.295*	1.3	.61	—	47	Good	.123
82	,,	Borgie	2.63	1.76	.87	—	50	Very good	.101
81	,,	,,	S.S.3.21	Nil	—	—	—	Critical for estab.	Peat soil
90	,,	Elibank	3.14 G.M.P.3.12*	2.31	.83		36	Fair response	.094
13	,,	Glentrool	2.58 G.M.P. 2.62*	.98	1.60	.95	163	Very good	Peat soil
6	,,	Twiglees	1.53	1.46	.07	.47	4.8	Whole plot badly frosted	.106
96	,,	Wauchope	3.25 G.M.P. 3.22*	3.13	.12	.46	3.8	None	.134
91	,,	Elibank	2.26	1.32	.94	—	71	Good	.083
108	Jap. larch	Wentwood	5.86	6.04	−.18	.81	−3	None	.075
83	,,	Borgie	2.20	did not survive	—	—	—	Critical for establ.	Peat soil
68	,,	Ferness	2.27	2.16	.11	.36	4	None	.089
85	,,	Clashindarroch	Not measured owing to deer damage					Not apparent	.184
86	,,	Bin	2.61	1.79	.82	1.05	46	Good	.060
4	,,	Aberhirnant	3.32	3.25	.07	.39	2.2	No response	.139
3	,,	,,	4.35	3.74	.61	.45	16	Slight	.129
115	,,	Myherin	3.11	2.53	.58	.66	23	,,	.133
122	,,	Coed Clwyd	6.36	6	.361	1.219	6.0	,,	.127
110	,,	Michaelston	3.78	3.39	.39	.51	12	,,	.118
113	,,	Glasfynydd	5.56	4.78	.73	1.02	16	,,	.086
100	,,	Allerston	5.26	3.73	1.53	.73	41	Very good	.059
114	,,	Brechfa							
A	,,	(ploughed)	5.36	4.76	.60	.46	13	Slight	.204
B	,,	(direct planting)	2.51	1.89	.62	.46	33	Very good	.204
111	,,	Rheola	4.66	4.38	.28	.62	6	None	.175
107	,,	Tintern	8.12	6.94	1.18	3.04	17	,,	.074
116	,,	Brynmawr	5.61	4.94	.67	.28	14	Slight	.128
2	,,	Dyfnant	4.95	4.27	.68	.54	16	,,	.119
103	,,	Allerston	5.25	5.13	.12	1.6	2.2	,,	.089

* G.M.P. comparative treatment with ground mineral phosphate.

Assessment of Manuring Effects, Growth Response, and Phosphate Content of the Soil

Table 41—*continued.*

Plot No.	Species	Forest	Manured Height Ft.	Control Height Ft.	Difference Ft.	Diff. req. for 5% sig. Ft.	% Height Increase	Growth Response	P_2O_5 Content %
88	Lodgepole pine	Fetteresso	1.66	1.60	.06	.46	3.75	None	.181
64	„	Inverinan	Control completely failed. Manured plot surviving but not vigorous					Critical for estab.	Peat soil
65	„	„							
81	„	Borgie	P.C. 1.01	Nil				„	.109
67	„	Leanachan	Manured plot survived only					„	Peat soil
84	„	Rumster	1.21	.88	.33	.29	38	Slight response	.102
77	Scots pine	Morangie	2.79	2.54	.25	.35	9.5	None	.086
71	„	Millbuie	1.60	1.50	.10	.3	6.3	„	.114
127	Corsican pine	Wareham	2.53	1.51	1.02	.49	68	Good	.054
128	„	„	2.93	2.01	.92	.91	46	„	.059
125	„	Purbeck	3.09	1.22	1.87	.85	153	„	.048
126	„	„	2.55	1.22	1.33	.55	109	„	.064

A TRIAL OF COMPOST IN PLANTING ON PEAT

By J. W. L. ZEHETMAYR

232.425

In 1938-39, three experiments were commenced at Inchnacardoch and Glen Righ Forests, Inverness-shire, on thin peat or blanket-moss over hard morainic knolls or slopes. They had two objects, the first to test the effect of compost (which had been shown by the late Dr. Rayner to give good results at Wareham forest in Dorset) on the growth of trees on peat soil, the theory being that the compost acted through the introduction of mycorrhiza; and the second to test a hypothesis that mycorrhiza might equally well be introduced by applying peat from actively growing plantations of the same tree species.

The compost used was that known as C_5 (Rayner and Neilson-Jones, 1944) composed of brewery hop waste and dried blood. For one experiment (Inchnacardoch 126) there was an additional test of C_5 and another compost, inoculated with different fungi, but these comparisons showed negligible differences and only the mean data are quoted.

The peat employed was selected from actively growing plots of the same tree species in older experiments, at Inchnacardoch and elsewhere.

Phosphate was already known to give excellent results and a comparison of the effect of ground mineral phosphate was also included, although the systematic design of this part of the experiments precluded a normal statistical comparison between the phosphate and the organic materials.

Four tree species were tested, Scots pine and lodgepole pine in all three experiments, Japanese larch in one, and Sitka spruce in two; two of the experiments were direct sowings, the third was planted. The results are expressed in terms of the height growth of the *pine* or *larch*, but as the percentage of losses of the *spruce*, since this species went into "check" or was suppressed by the pine, and the results were thus recorded at an earlier age.

Effects of Compost and Peat on Growth of Pines and Sitka Spruce

Table 42 Height in feet or percentage losses

Method	Plantation				Direct Sowing							
Experiment	Glen Righ 36.P.38				Inchnacardoch 121.P.38				Inchnacardoch 126.P.39			
Age at Assessment	9 yrs.				S.P. & P.C. 15 yrs. S.S. 7 yrs.				Aged 15 yrs.			
Ground Preparation	Inverted replaced turf				Dug-over patches				Turf and drain			
	Dose	S.P.	P.C.	J.L.	Dose	S.P.	P.C.	S.S.*	Dose	S.P.	P.C.	SS*
Control	—	2.7	3.8	3.1	—	2.3	3.3	100%	—	3.5	3.1	100%
Peat	1 lb.	3.4	5.2	4.6	1 lb.	2.5	3.8	90%	½ lb.	3.9	4.1	100%
Compost	2 lb.	4.9	5.4	5.4	2 lb.	5.0	8.0	20%	1 lb.	5.8	5.7	50%
		**		*		**	**			*		
S.E.		±0.25	±0.5	±0.5		±0.15	±0.23	—		±0.44	±0.52	–
Diff. for 5%		1.0	—	1.9		0.5	0.8	—		1.5	2.0	–
significance 1%		1.4	—	—		0.8	1.2	—		—	—	–
G.M.P. comparison	2 ozs	4.3	5.1	6.0	4 ozs	5.9	8.0	0%	1 oz	7.8	8.0	10%

Notes: Means of four replications in each experiment. S.P.=Scots pine; P.C.=Lodgepole pine; J.L.=Japanese larch. S.S.=Sitka spruce. G.M.P.=Ground Mineral Phosphate.

* Figures for S.S. are approximate percentage losses. S.S. was suppressed by pines in Expt. 121, and checked in Expt. 126.

The results are given in Table 42 and may be summarised thus:

COMPOST. Of seven comparisons available for the heights of pine and larch, compost caused a significant increase in five cases, and an almost significant increase in one case, but in the seventh, lodgepole pine (*Pinus contorta*) at Glen Righ, the site variation as indicated by the high standard error was too irregular to give significant results. In the two comparisons with spruce, compost caused a considerable reduction in losses.

PEAT. In no case did peat increase the growth of the pines or larch significantly; the one case where increase in growth was almost equal to that due to compost was in the lodgepole pine at Glen Righ, already noted as being on an irregular site. The losses of spruce were not reduced by the application of peat.

PHOSPHATE. The peat and compost-treated plots were split systematically for the application of ground mineral phosphate. Of the seven comparisons on pine and larch, the effect of the phosphate was about the same as that of the compost in five cases, and rather greater in two cases. The reduction in the spruce losses was greater than with compost.

DISCUSSION OF THE RESULTS. The organic materials used in these experiments were not analysed, but many later analyses indicate that C_5 compost contains about one per cent P_2O_5. The normal P_2O_5 content of ground mineral phosphate is about sixteen per cent, and the P_2O_5 content of the various manurial doses is shown in Table 43.

The results in terms of P_2O_5 are not inconsistent with the action of the compost being mainly manurial. The fact that the peat from actively growing plantations (and bearing mycorrhiza) was wholly ineffective, suggests that the introduction of mycorrhiza is not an important factor.

Compost seems to give rather more than its worth (in terms of P_2O_5 supplied) in Glen Righ Expt. 36, but considerably less in Inchnacardoch Expt. 126 (Table 43).

Relationship Between the Heights of the Trees and the Probable Amount of P_2O_5 applied

Table 43

Experiment	Fertiliser	Dose and P_2O_5 Content	Amount of P_2O_5	Heights, feet S.P.	P.C.	J.L.	Mean Ht. feet
Glenrigh, 36	Control	—	—	2.7	3.8	3.1	3.2
(Inverted replaced turf)	Compost	2 lbs. at 1%	less than $\frac{1}{3}$ oz.	4.9	5.4	5.4	5.3
	G.M.P.	2 ozs. at 16%	c. $\frac{1}{3}$ oz.	4.3	5.1	6.0	5.1
Inchnacardoch 121	Control	—	—	2.3	3.3	—	2.8
(Dug-over patches)	Compost	2 lbs. at 1%	less than $\frac{1}{3}$ oz.	5.0	8.0	—	6.5
	G.M.P.		c. $\frac{2}{3}$ oz.	5.9	8.0	—	6.9
Inchnacardoch 126	Control	—	—	3.5	3.1	—	3.3
(Turf and drain)	Compost	1 lb. at 1%	less than $\frac{1}{6}$ oz.	5.8	5.7	—	5.8
	G.M.P.		c. $\frac{1}{6}$ oz.	7.8	8.0	—	7.9

Notes. S.P.=Scots pine. P.C.=Lodgepole pine. J.L.=Japanese larch.

The very small residual effect of the compost, and the effect of the peat, could well be due to the supply of other nutrients or possibly to the physical amelioration of the sowing or planting spot. This is supported by the suggestion that in five cases out of seven, the effect of the phosphate has increased, relative to that of the compost, between the assessments for the seventh to ninth years, and that for the fifteenth year. Mean values are given in Table 44.

Conclusion

While the effectiveness of large doses of compost in promoting growth has been demonstrated in both direct sowings and plantings on peat, equivalent effects are produced by much smaller quantities of ground mineral phosphate. On considering the quantity of phosphate likely to be present in the compost, it is evident that there is little need to seek beyond the straightforward manurial effect for the explanation of the major portion of the effect of compost, and that the very small residual effect of the compost, together with that of the peat (which has virtually no P_2O_5 content), could be due to temporary amelioration of physical conditions at the sowing or planting spot, operative mainly in the first few years.

Heights at Seven to Nine Years and Fifteen Years, and their Differences

Table 44 All species

Treatment	Mean height after 7/9 years feet	Mean height after 15 years feet	Increment feet
Control	1.8	5.4	3.6
Peat	2.4	7.0	4.6
Compost	3.4	9.1	5.7
Ground Mineral Phosphates	3.4	10.2	6.8

REFERENCE

Rayner, M. C. and Neilson-Jones, W. 1944. *Problems in Tree Nutrition.* Faber and Faber, London.

THIRD REPORT ON AN INVESTIGATION OF 1931-32 INTO VARIOUS RACES OF EUROPEAN LARCH

By M. V. EDWARDS

Summary of the Nursery Stage

232.12: 174.7

In 1929 an experiment comparing the production and growth of plants from seed of different provenances of European larch (*Larix decidua* Mill. = *L. europea* D.C.) was commenced in six different nurseries in Scotland. Seed from two Scottish and two Continental sources was used. The two Scottish provenances came from trees at Elchies (Morayshire) and Dores (Inverness-shire). These are not, of course, native, but are from old trees planted before importations of continental seed became common, and there is therefore a possibility that they are of the "Dunkeld" strain. The evidence has been discussed by Anderson (1932, pp. 8-10).

The Silesian seed was obtained through a seed merchant and was said to be from a larch stand growing in Silesia but of Sudeten parentage. That it was genuine Sudeten origin, one of the type sometimes called *Larix decidua* var. *sudetica* Domin., later appeared doubtful (*see* Macdonald, 1937). Its behaviour in the nursery was similar but rather inferior to that of the Scottish provenances.

The seed from the Münsterthal, where Switzerland adjoins Austria and Italy, came from a commonly used source of larch seed, and may be considered a typical example of high altitude Alpine larch. For further details of all origins see the Seed Provenance Data following on page 153.

Production of Larch of Four Provenances

Table 45 Mean data for seed sown at six Scottish Nurseries

Münsterthal	Silesia	Dores, Inverness-shire	Elchies, Morayshire
Total production of all plants, in thousands. 2-year seedlings.			
8.7	12.1	11.2	14.6
Production of plants over 6 ins. tall fit for planting, in thousands			
4.7	6.0	6.5	8.0
Mean height of the 2 per cent tallest seedlings, in inches.			
13.3	12.7	13.9	13.8

Notes. The above data calculated from Anderson (1932) Table III. Data for the Münsterthal provenance per pound of seed sown. Data for other provenances adjusted to compensate for differences in seed purity, size and germination capacity.

Production of Larch at Six Nurseries

Table 46 Mean data for seed of four provenances, two-year seedlings

Nursery	Total production of plants, in thousands	Production of plants over 6 ins. tall fit for planting, in thousands	Mean height of the 2 per cent tallest seedlings, in inches
Ratagan	14.6	1.5	7.1
Altonside	7.1	4.3	11.0
Auchterawe (i.e. Inchnacardoch)	14.0	8.1	10.5
Barcaldine	11.8	7.6	9.7
Drumtochty	13.6	8.2	17.3
Inverleith (i.e. Royal Botanic Garden, Edinburgh).	8.7	8.0	24.8

Note. Above data calculated from Anderson (1932), Table III.

The results of the nursery stage of the experiment were described by M. L. Anderson (1932). Very briefly, the results showed that, after making due allowance for variations in the size and viability of the seed, as determined by laboratory test, the production of plants was highest from seed collected at Elchies, Morayshire; and lowest from seed collected in the Münsterthal, Switzerland (See Table 45). The rate of germination of the Elchies seed was the most rapid. Calculated on the basis of the mean height of two per cent of the tallest plants in each seed lot, there was little difference between the four provenances, but on the basis of the number of plants over six inches in height (as two-year seedlings) fit to line or plant out, the Elchies provenance was again the best, and the Münsterthal very much inferior. In general, the second Scottish provenance, from Dores, gave results only slightly inferior to that from Elchies.

Other differences in colour of foliage and bark, and in the susceptibility of the provenances to attack by rabbits, were also noted. The differences in the size of the plants varied considerably in the different nurseries. (See Table 46.) These differences are of importance in distinguishing at a later stage between the inherited characteristics due to provenance and less permanent differences due to varying nursery conditions.

Mean Heights in 1935 or 1936, for Seedlings and Transplants, of Four Larch Provenances Planted in Three Forests

Table 47 Mean data for plants from six nurseries. Feet

Forest	Plant	Münsterthal	Silesia	Dores	Elchies	Means
Lael, Wester Ross	S	7.2	8.2	8.9	8.0	8.1
	T	6.3	6.8	8.1	6.8	7.0
	Mean	6.7	7.5	8.5	7.4	7.5
Drummond Hill, Perthshire	S	4.2	4.5	5.1	4.7	4.6
	T	3.2	3.6	3.8	3.4	3.5
	Mean	3.7	4.1	4.5	4.1	4.1
Clashindarroch, Aberdeenshire	S	1.3	1.3	1.4	1.6	1.4
	T	1.4	1.5	1.8	1.6	1.6
	Mean	1.3	1.4	1.6	1.6	1.5
Mean of above Forests	S	4.2	4.7	5.1	4.8	4.7
	T.	3.6	4.0	4.6	3.9	4.0
	Mean	3.9	4.3	4.9	4.4	4.4
Radnor	S	3.1	3.0	3.8*	2.8	3.2
	T	3.0	3.2	4.3*	3.1	3.4
	Mean	3.1	3.1	4.0*	3.0	3.3

Notes. S=Seedlings. T=Transplants. *=Braco Wood.

Scottish data from Macdonald, (1937): p. 36-38; Radnor data from R. D. Pinchin (unpublished). All plants same age from seed. Transplants five years old in forest, and seedlings six years old in forest in Scottish experiments. At Radnor four and five years respectively.

Early Growth in the Forest

The experiments were then extended into three forests in Scotland, two-year seedlings in 1931 and two-year—one-year transplants in 1932, and the results after five to six years' growth were reported by J.A.B. Macdonald (1937). There are three identical experiments, located at Lael Forest (on the north-west coast above Loch Broom, low elevation, mild moist climate); Drummond Hill Forest (in central Perthshire, medium elevation and moderate climate); and Clashindarroch Forest (in Aberdeenshire, high elevation and a poor exposed site). In each experiment, all the six nurseries were separately represented by groups of thirteen plants, i.e. the spaced group system of planting (Anderson, 1951), both of seedlings and of transplants, all from the same seedbeds. The twelve groups so obtained form one unit of each provenance. These were replicated nine times in each forest. The plots were not randomized, so that analysis of the variance of the results is not justifiable, but the distribution of the plots is so wide that the data are unlikely to be biased by variability of site within each experiment.

At this time comparable results were obtained from another experiment of the same date and general design. This had been carried out in the English nurseries of Nagshead in the Forest of Dean, and Kennington, near Oxford, at the same time as the Scottish experiment, and planted in Radnor Forest in Wales. The experiment employed the same lots of seed except for the substitution of Braco seed from Aberdeenshire for that from Dores. In this experiment the plots were laid out in the form of a Latin Square and the results can be compared statistically. Table 47 shows in its "Radnor Data", that the results follow the same pattern as those for the Scottish experiments, the general level of growth being intermediate between that at Drummond Hill and at Clashindarroch.

Macdonald's report shows that the biggest differences in the Scottish experiments were those due to the differences in the location of the three forests. At Lael Forest the losses after planting were least and the height growth far the greatest. At Clashindarroch Forest, the opposite extreme, the height growth after five to six years was on the average less than one-quarter that at Lael. (See Tables 47, 48 and 49, compiled from Macdonald's data and including Radnor data in Table 47.) Among the different provenances, the Münsterthal lot gave the poorest crop, with both fewer successful plants, and with smaller plants. The differences between the remaining three provenances were small, but Dores (or Braco) achieved the first place, both in survival and height growth, instead of Elchies which had been the best in the nursery.

In comparing the out-turns of the six nurseries, it may be noted that Inchnacardoch (Auchterawe) Inverness-shire; Barcaldine, Argyll; Drumtochty, Kincardine; and the Royal Botanic Garden, Edinburgh (Inverleith) nurseries all produced good plants, whether assessed by the number over six inches tall or by the height of the tallest two per cent of the plants. Ratagan, Inverness-shire and Altonside, Moray, nurseries produced poor results as assessed by the number of plants over six inches, but at Altonside, if judged by the height of the tallest two per cent of the plants, production was relatively very good. Ratagan plants were the worst by either standards of assessment (see Table 46). At an age of five or six years, the average height of the Ratagan and Altonside plants was less than that for other nurseries (Table 48), thus following the trend of the nursery data for plants over six inches tall (Table 46), but not so closely the data for the height of the tallest two per cent of the plants. Probably this latter measure of assessment was too refined and did not take into account a sufficient proportion of the population. It may be assumed that the forest experiments included a good deal more than two per cent of the total seedling production.

Mean Height in 1936 of Plants from Six Nurseries

Table 48. Mean data for four provenances, both seedlings and transplants. Feet.

Forest	Ratagan	Altonside	Inchnacardoch (Auchterawe)	Barcaldine	Drumtochty	Royal Botanic Garden, Edinburgh	Means
Lael	7.1	6.7	8.2	7.9	7.3	8.1	7.5
Drummond Hill	3.7	3.7	4.3	4.5	3.8	4.4	4.1
Clashindarroch	1.3	1.2	1.6	1.5	1.5	1.8	1.5
Mean	4.0	3.9	4.7	4.6	4.2	4.8	4.4

Notes. Data from Macdonald, (1937), p. 34-35. Age 5 to 6 years.

Mean Survival in 1936, as Percentage of Trees Planted: Four Larch Provenances from Six Nurseries Planted in Three Forests

Table 49

<table>
<tr><td>Forests:</td><td colspan="2">Lael</td><td>Drummond Hill</td><td colspan="3">Clashindarroch</td><td>Grand Mean</td></tr>
<tr><td>Average of all provenances, nurseries, seedlings, and transplants.</td><td colspan="2">88</td><td>73</td><td colspan="3">73</td><td>78</td></tr>
<tr><td>Provenances:</td><td colspan="2">Münsterthal</td><td>Silesia</td><td colspan="2">Dores</td><td>Elchies</td><td></td></tr>
<tr><td>Average of all forests, nurseries, seedlings, and transplants</td><td colspan="2">72</td><td>78</td><td colspan="2">81</td><td>79</td><td>78</td></tr>
<tr><td>Nurseries:</td><td>Ratagan</td><td>Altonside</td><td>Inchnacardoch (Auchterawe)</td><td>Barcaldine</td><td>Drumtochty</td><td>R.B.G. (Inverleith)</td><td></td></tr>
<tr><td>Average of all forests, provenances, seedlings and transplants</td><td>76</td><td>74</td><td>88</td><td>79</td><td>66</td><td>81</td><td>78</td></tr>
<tr><td>Type of Plant:</td><td colspan="3">Seedlings</td><td colspan="3">Transplants</td><td></td></tr>
<tr><td>Average of all forests, provenances and nurseries</td><td colspan="3">76</td><td colspan="3">79</td><td>78</td></tr>
</table>

Notes. Data calculated from Macdonald, (1937). Age 5 to 6 years.

The average survival and growth of the four provenances and of the plants from each of the nurseries followed the same pattern in all three forests. But this was not true of the behaviour of the seedlings and transplants, which showed an interaction with the site factors. At the two favourable forests, Lael and Drummond Hill, the seedlings grew rather taller than the transplants, the mean differences being nearly a foot, or some fifteen to twenty-five per cent. But at the difficult sites of Radnor and Clashindarroch, the transplants had a slight advantage. These differences are the more remarkable when it is remembered that the transplants were planted a year later than the seedlings, but they are in agreement with other experimental work on the behaviour of different types of plants, which has shown that seedlings often do better in easier localities but transplants have an advantage in places where conditions are more severe.

Mean Height in Spring, 1946, for Seedlings and Transplants of Tallest Tree per Group. Four Larch Provenances in three Forests

Table 50 Feet

Forest	Plant	Münster-thal	Silesia	Dores	Elchies	Means
Lael	S	31.1	32.7	33.3	32.1	32.3
	T	30.0	30.9	32.5	31.2	31.2
	Mean	30.6	31.8	32.9	31.6	31.7
Drummond Hill	S	22.8	23.8	24.1	23.2	23.5
	T	21.3	21.4	22.1	20.9	21.4
	Mean	22.0	22.6	23.1	22.0	22.4
Clashindarroch	S	4.8	5.6	9.4	7.0	6.7
	T	5.1	5.7	9.1	8.1	7.0
	Mean	5.0	5.6	9.2	7.6	6.8
Mean of above forests	S	19.6	20.7	22.3	20.8	20.8
	T	18.8	19.3	21.2	20.1	19.9
	Mean	19.2	20.0	21.8	20.4	20.3
Radnor	S	10.5	10.7	13.6*	12.5	11.8
	T	12.0	12.1	15.1*	13.3.	13.1
	Mean	11.2	11.4	14.4*	12.9	12.4

Notes: Seedlings age fifteen from planting, transplants age fourteen years.

S = Seedling. T = Transplant. * = Braco Wood.

In 1946 another assessment of these experiments was made. In this case, only the tallest tree in each group was measured. Table 50 shows that the differences between the three forests had increased greatly, the height of the trees at Lael being over four times that at Clashindarroch. The differences between the provenances were also greatly changed. At Lael Forest, the differences in 1936 of nearly 1.8 feet, or twenty-one per cent, between the best and worst provenances had decreased proportionately to the size of the trees and were roughly two feet in thirty, or four per cent. But at Clashindarroch the small differences of 0.3 feet or nineteen per cent in 1932 had increased to 4.2 feet, or forty-seven per cent, the Münsterthal provenance thus being little over half the height of the best (Dores) provenance. Differences between the plants from various nurseries still persisted, Ratagan and Altonside plants still being in arrears.

At the same time the assessor (W. B. R. Laidlaw) examined the form of the trees. They had then grown beyond the juvenile types depicted in Macdonald's report of 1937, and it did not prove possible to correlate the shape of the tree and its branches with the provenance of the seed. From a study of these and related experiments, Dr. Laidlaw concluded that "The high Alpine European types are squat sub-fastigiate (in growth) with notably stout branches, short, stout twigs and long heavy abundant green foliage. Compare this with a continental lower elevation type, e.g. Silesian. The outstanding characters which immediately strike the eye on studying a young tree are the mesh of very fine interlacing twigs and light, thin, comparatively short and often sparse foliage." This difference is most marked with certain examples of true Sudeten larch, some of which have been received from Silesia, and grown in other experiments.

Results after Approximately Twenty Years

HEIGHT. In 1949-53, further studies were made. In all experiments, measurements were made on the basis of the two tallest trees per group, which was thought to be more reliable (Table 51). A check, however, revealed that this made no difference in comparing the different provenances or other treatments included in the experiments, although of course the general mean based on one tallest tree per group is slightly higher than the mean based on the two tallest trees.

Mean Height in 1949 to 1953, for Seedlings and Transplants, of Two Tallest Trees Per Group: Four Larch Provenances in Three Forests

Table 51 — Feet

Forest and date of assessment	Plant	Age	Münsterthal	Silesia	Dores	Elchies	Means
Lael	S	19	37.2	39.1	39.7	38.1	38.5
(1949)	T	18	36.8	37.3	39.3	37.9	37.8
	Mean		37.0	38.2	39.5	38.0	38.2
Drummond Hill	S	22	33.1	33.8	34.3	33.1	33.6
(1952)	T	21	32.2	32.0	33.4	31.9	32.4
	Mean		32.6	32.8	33.8	32.5	32.9
Clashindarroch	S	20	8.1	8.5	13.1	9.8	9.9
(1950)	T	19	8.2	8.4	12.1	11.3	10.0
	Mean		8.1	8.5	12.6	10.6	10.0
Mean of above forests	S	—	26.1	27.1	29.0	27.0	27.3
	T	—	25.7	25.9	28.3	27.0	26.7
	Mean		25.9	26.5	28.6	27.0	27.0
Radnor	S	23	17.3	17.9	24.6*	21.3	20.3
(1953)	T	22	19.0	19.4	25.4*	22.5	21.6
	Mean		18.1	18.7	25.0*	21.9	20.9

Notes: Standard error of means in Radnor experiment $\pm$ 0.77. Differences significant at 5 per cent level. Plants of Braco significantly taller than Elchies, and both these significantly taller than Münsterthal and Silesia.

S = seedlings; T = transplants; * = Braco.

The growth at the different forests cannot be compared exactly, as the experiments were not all assessed in the same year, but they continued to follow the previous pattern. At Lael, the crop was ready for its second thinning whereas, at Drummond Hill, the first thinning was due, but at Clashindarroch the canopy had never closed up and the future of the crop was in doubt. The growth at Radnor had been rather slower than at Drummond Hill, but much better than that at Clashindarroch.

As regards the height growth of the four provenances, the conclusions drawn in 1946 were confirmed, although the differences at Clashindarroch forest do not appear so marked. At all forests, the tallest provenance is that from Dores or its substitute, Braco, in the Radnor experiment, and the shortest is Münsterthal. At Lael and Drummond Hill, the two most favourable sites, the growth of all provenances was almost equal, but at Radnor and Clashindarroch that of the Scottish provenances was very much greater than either of the foreign ones.

These results indicate that the provenance of the seed has important effects on the growth of larch, but that these effects are much larger on limiting sites under difficult conditions of climate and soil than they are on favourable sites, where, among the provenances tested, the differences were negligible.

In particular, the conclusion that the Münsterthal provenance is a particularly poor one, derived from much experience and experimentation, is confirmed (Forestry Commission, 1947). A Silesian provenance has proved to be little better, and not of the superior Sudeten parentage that it was reported to come from.

Although in other experiments it has been difficult to distinguish between the crops from seed of different Scottish larch stands, in this case there is a marked superiority of the Dores and Braco provenances over that of Elchies, both being themselves superior to the foreign provenances.

A comparison, at this stage, of nursery origins appears in Table 52, and is discussed later.

Mean Height in 1949/52 of Plants from Six Nurseries

Table 52 Mean data from four provenances, seedlings and transplants Feet

Forest	Ratagan	Altonside	Inchnacardoch (Auchterawe)	Barcaldine	Drumtochty	Botanic Garden, Edinburgh	Means
Lael	38.4	37.8	38.4	38.0	37.8	38.7	38.2
Drummond Hill	32.1	33.0	33.0	33.7	33.0	33.0	33.6
Clashindarroch	9.4	9.6	10.3	10.2	10.2	9.9	10.0
Means	26.6	26.8	27.3	27.3	27.0	27.2	27.0

BASAL AREA. In the Radnor experiment, measurements of the basal area of the two dominant trees per group followed the same pattern, the basal areas of both Braco and Elchies being significantly greater than those of the Münsterthal and Silesian provenances (Table 53).

SURVIVAL. A significant characteristic, not recorded before, is the number of groups of thirteen originally-planted trees in which two or more trees still survive. This data shows that whereas at Lael, Drummond Hill and Radnor forests a complete crop has been obtained, at Clashindarroch there are many groups with less than two trees (and some completely blank), and of course many with two or more trees which are by no means fully stocked. (Table 54.) The deficiencies are greatest in the Münsterthal plots, and an inspection shows plainly that although the Scottish provenances are growing slowly they will probably in due course form a complete crop, whereas there will be a very long delay before this happens, if at all, with the Münsterthal provenance. On such an exposed site where vigorous heather (*Calluna vulgaris*) still covers the ground, early canopy formation is of special importance.

Basal Area of Groups of Plants of Four Provenances: Radnor Forest

Seedlings and Transplants. Mean data from two nurseries.

Table 53 Square feet per group

Type of Plant	Münsterthal	Silesia	Braco	Elchies	Means
Seedlings	.053	.065	.092	.080	.072
Transplants	.058	.064	.094	.080	.074
Mean	.055	.065	.093	.080	—

Note: Standard error of means of provenances ± 0.0049. Differences significant at 5% level.

DIFFERENCES DUE TO NURSERY TREATMENT. In 1949-52 the overall mean for all the plants, seedlings and transplants, from Ratagan and Altonside nurseries was still lower than that of any other nursery (Table 52), showing how long a small difference in size of plant can persist. At Lael, the differences between the best and worst nursery stock was only some two per cent of the height of the trees, but at Clashindarroch it was about ten per cent and again there is evidence of the greater importance of early differences on the poorer planting sites.

Percentage of Groups in Which Two or More of the Thirteen Planted Trees were Surviving in 1951: Clashindarroch Forest

Table 54 Seedlings and Transplants

Type of plant	Münsterthal	Silesia	Dores	Elchies	Means
Seedlings	61	78	93	89	80
Transplants	72	81	96	93	86
Mean	66	80	94	91	83

Note: At Lael and Drummond Hill forests, the majority of plants in all groups survived until suppressed by adjacent trees.

Phenology

Time of Leaf-flushing

In 1930, Anderson remarked that, when the larches were still in the nursery stage, the order of leaf-flush in two nurseries was undoubtedly: Silesian, Münsterthal, Elchies and Dores, but that in a third nursery the effect of different degrees of shelter on the seed beds obscured any effect due to provenance.

When the larches planted in Lael Forest were five to six years old, the order was found to be: Silesian, Münsterthal, Dores and Elchies, in the seedling section of the experiment, but this order was less clearly marked for the transplant section. In the other two Scottish experiments less detailed records were made, but it appeared that the Silesian were the earliest and Elchies the latest plants to flush.

In the spring of 1948, an assessment was made in the experiment at Radnor by comparing the flushing branches with standard photographs. These define the stage of flushing as I, the winter resting state; II, the swelling of the buds; III, the bursting of the buds; IVa, emergence of needles; and IVb, when the tip of the leading shoot has extended to the same distance as the extremities of the needles.

R. D. Pinchin, in an unpublished paper, showed that in 1948 at the most critical phase (March 11th) the order of flushing was found to be: Münsterthal (85 per cent), Silesia (25 per cent), Braco (15 per cent) and Elchies (10 per cent) as a percentage of trees which on the average had reached stage III. The remaining trees were all in stage II, except for thirty per cent of the Elchies trees in stage I. The following year (1949) observations indicated that the flushing order "was substantially the same".

In 1949 assessments were made at Drummond Hill. Twelve trees of each provenance were selected at random, four in each block of the experiment, half being dominant and half being sub-dominant trees. Though there was considerable variation among individuals, the means were all close together. The average of the earliest and latest provenances to reach stage II were within four days (March 4th and March 7th), and the same small differences persisted through later stages, but with different provenances coming first or last. It was concluded that there were no significant differences in date of flushing between the provenances, but that this might have been due to the mildness of the spring, and might not be true in a more severe season.

A similar assessment was carried out at Clashindarroch, but owing to the continual dying back of branches selected for assessment, and the selection of others to take their place, two separate samples were, in fact, obtained. The order of flushing was not constant for the two samples, and the pattern of mean differences between the provenances was comparable to that at Drummond Hill; these differences were far from significant.

A further assessment was made in 1951 to try and estimate the effect of different seasons, but again similar results were obtained.

The evidence is, therefore, somewhat contradictory, and though in some cases there is definite evidence that the Scottish provenances flush later than Continental ones, this is by no means always true. At least under certain conditions, very precise investigations would be needed to establish any differences characteristic of a provenance, and in many cases it seems probable that factors other than inherited ones are responsible for differences in times of flushing.

Time of Leaf-fall

Macdonald (1937) remarked that in 1935, the Elchies provenance retained its needles longer than others, but observations in these experiments in several recent years did not reveal any differences.

Resistance to Larch Canker

All the experiments were subject to the occurrence of larch canker. These consist of patches of dead tissue, the result of the complex caused by frost and

Trichoscyphella hahniana and *T. wilkommii* (*Dasyscypha wilkommii*). As the annual rings are laid on around the dead area, the cankers assume a characteristic crater-like shape.

An assessment of the number of such cankers in the Scottish experiments was made in the years 1949 to 1952, when cankers were counted on the stems of all the dominant trees whose heights were recorded, from ground level up to a height of ten feet. At Drummond Hill, cankers were rare, and only about twenty per cent of the trees were affected at all, but trees of all provenances suffered. The mean number of cankers varied from a maximum of 1.1 per tree for Münsterthal to a minimum of 0.7 for Dores. These figures represent a percentage of fifty-one per cent of Münsterthal trees affected, to forty-four per cent of Dores trees. At Radnor, a partial assessment was made on a basis of number of square inches per tree affected by canker, and the results were as follows: Münsterthal 8.8, Silesia 5.6, Elchies 5.5, and Braco 3.6 However, these differences were not shown to be significant by the method of assessment employed.

Though the experiments do not afford any significant data as to resistance to canker, they suggest that such differences exist, but that they are greater between the different experimental sites than between the provenances represented.

Discussion of the Provenance Factors

There are difficulties in interpreting the results of a provenance experiment of this nature when only the immediate parentage of the seed is exactly known and where the ancestry of all but one of the four provenances used is uncertain. That the Münsterthal seed came from trees natural to that region is unquestionable. The seed from Silesia, of reputed Sudeten origin, has, however, not produced results in any way comparable with later importations of seed of guaranteed Sudeten origin, from *Larix decidua* var. *sudetica* Domin. The true Sudeten larch is a tree with much smaller, rounder cones (Rubner, 1943), with greyer twigs and needles, and with more pendulous branchlets in youth, resembling rather the Carpathian or Polish larch than the Alpine. Its appearance in experiments younger than those reported here is quite distinctive. Although this tree is grown in Silesia, Alpine larch also is grown there, and the appearance and behaviour of the plants from Silesian seed used in this experiment suggest that they may be of Alpine stock.

The two Scottish provenances of Braco and Dores have given outstandingly good results and may be classed as "good Scottish provenances". That for Elchies has been proved inferior in several respects, and neither these results nor the appearance of the one surviving forest tree, which bears several points of resemblance to Alpine larch, indicates that it could be considered as a good Scottish provenance.

Conclusions

Although obvious, it is perhaps desirable to note first that the biggest differences were those between the growth of the larches of all provenances, at the four sites chosen for the experiment. These were selected as being highly favourable, intermediate and marginal as regards their suitability for European larch.

A rather higher percentage of success at establishment was obtained at the more favourable sites than at the others, and the Scottish provenances were slightly more successful, on the average, than the foreign. At the age of about twenty years, successful crops had been obtained at both the favourable and the two intermediate sites, but at the marginal site the differences between provenances were most marked. Over ninety per cent of the plants of both Scottish origins survived, as compared to eighty per cent for the Silesian and about sixty-six per cent for the high Alpine provenance.

Considering the height growth of the provenances, these have proved little different on the most favourable and intermediate sites, but at the marginal site, the growth of the two Scottish provenances has been markedly better than that of the two foreign ones, and though these did not differ much, the high Alpine source was the poorest. The growth of the Braco and Dores provenances was markedly better than that from Elchies, while the height growth of the best Scottish provenance was fifty per cent greater than that of the foreign provenances.

REFERENCES

Anderson, M. L. 1951 — Spaced Group Planting and Irregularity of Stand structure. *Empire Forestry Review 30* (4) : p. 328-41

Anderson, M. L. 1932 — Report on the Preliminary Stages of an Investigation into Various Races of European Larch. *Scot. For. J. 46* (1) : p. 7-27. Illus.

Macdonald, J. A. B. 1937 — Second Report on a Forestry Commission (Research Branch) Investigation into Various Races of European Larch. *Scot. For. J. 51* (1) : p. 30-38. Illus.

Forestry Commission 1947 — *Twenty-Seventh Annual Report for the Year ending September* 30*th*, 1946 : p. 36

Rubner, K. 1943 — Das areal der Sudeten Larch. *Tharandter forstliches Jahrbuch 94* (1-3) : p. 1-99

SEED PROVENANCE DATA

Münsterthal: Supplied by J. J. Roner, and therefore probably from Switzerland. (The Münster Thal is partly in Canton Grisons but also partly in that part of the Tyrol which was Italian in 1927 but Austrian before 1918: hence former description as "Austrian Tyrol".
46° 35′-38′ N. 10° 20′-27′ E. 1927 crop, Id. No. 28/30.

Silesia: Reputed Sudeten, but this is doubted. Supplied by K. Gebauer. 1928 crop. Id. No. 29/27.

Dores, Aldourie Estate, Inverness-shire: Six fine straight-stemmed trees about seventy feet high, planted about 1825. 57° 23′ N. 4° 19′ W. Elevation 100-200 ft. 1929 crop, but many old cones. Id. No. 29/525.

Elchies Estate, Morayshire: Eight fine old trees, over 100 years old. A survivor beside Easter (not Wester) Elchies churchyard, was eighty-eight feet high, girth 11 feet 2 inches in 1951. 57° 29′ N. 3° 2′ W. Elevation 500 feet to 600 feet. 1929 crop. Id. No. 29/524.

Braco Wood, Monymusk, Aberdeenshire: 57° 16′ N. 2° 31′ W. Trees sixty to seventy years old. Elevation 800 feet. 1928 crop. Id. No. 29/509. Presented by Messrs. A. and G. Paterson Ltd. (This wood is now part of Benachie, formerly Tilliefoure, Forest, Compartments 68 & 69.)

Experimental Site Data

	Braemore, Lael Forest, Wester Ross	Dalerb, Drummond Hill Forest, Perthshire	Mytice, Clashindarroch Forest, Aberdeenshire	Glydre, Radnor Forest, Radnorshire
Latitude and Longitude	57°47′ N. 5°2′ W.	56°35′N. 4°1′ W.	57°22′ N. 2°51′W	52°17′ N. 3°10′W
Elevation, ft.	180-330	900-1,050	1,000-1,150	1,400-1,550
Relative elevation	About 120 ft. above floor of valley and 2 miles above tide limit on Loch Broom. Hills to 1,500 ft. to North	550-700 ft. above Loch Tay. 300 ft. below summit of Drummond Hill.	250-350 ft. above valley bottom. Hill to 1,700 ft. above expt.	—
Exposure	Sheltered	Moderate	Moderate	Severe
Aspect	S.W.	S.S.E.	N.	N.
Slope	Steep to very steep 25°-30°	Steep to very steep.	Steep or moderately steep. 15°-25°	Very steep. 30°
Topography	An even slope	An even slope	An even slope	Even slope, less steep both below and above.
Geology	Muscovite—biotite pelitic schists of the Moine series.	Highland mica schists of the Dalradian succession.	Highland schists: slates of the MacDuff group, Dalradian succession.	Silurian shales
Soil	0-2 in.: F. & H. layer. Needles. 2-5 in.: Mull humus. 5 in.-25 in.: Sandy loam, light yellow. Soft crumb structure. Friable.	0-12 in.: Loam, brownish grey, soft crumb structure, friable. 12 in. - 40 in.: Light medium loam, fairly compact yet free.	0-4 in.: F. layer. Mor. 4 in.-12 in.: Olive-grey gritty sand. 12 in. - 30 in.: Slate loam, porous, free, rusty brown.	Shallow brown earth, podsolized in the higher parts of the experiment.
Rainfall....	60 in. per annum.	40 in. per annum.	35 in. per annum.	45 in. per annum.
Vegetation before planting	*Agrostis* sp. *Aira flexuosa* *Pteridium aquilinium*, *Holcus* spp. *Juncus* spp. in hollows.	Mixed crop of larch, spruce, Scots pine, sycamore, beech, etc.	*Calluna vulgaris*, *Vaccinium* spp. *Erica cinerea* and *Polytrichum*, *Sphagnum*.	*Calluna vulgaris*, *Vaccinium* spp. *Pteridium aquilinium* and grasses locally abundant.
Expt. No.	1.P.31	5.P.31	1.P.31	23, P.31-32

FECUNDITY OF BUPALUS PINIARIUS IN BRITAIN, 1955

By D. BEVAN and A. PARAMONOV

145.7

AMONG THE BASIC DATA required in connection with the work on the Pine looper, *B. piniarius* L. is detailed information on the variation and range of fecundity of the female.

Until J. Stahl (1939) in Germany and A. Iljinskij (1941) in Russia, investigated the matter, workers wishing to find average field fecundity had to rely on rough annually made estimates, based on data from adults bred from pupae collected in the particular forest in which they were working. These estimates, due possibly to bias in the sample or to size of sample, tended to give unsatisfactory results.

It will be readily appreciated that once the correlation between weight of female pupa and the corresponding fecundity of the emerged adult has been established for a particular insect species, it is then an easy matter, in normal populations, to find average fecundity by merely weighing a field sample. The experiment to be described, aimed to check previous continental work and to provide an extension of the correlation to cover our lower range of pupal weights.

Method

Pupae were collected in Clipstone Forest, Nottinghamshire, during the winter of 1954 to 1955. The females were individually weighed and divided into 12 weight classes as follows:

Weight	*Number of Pupae*
0.045 - 0.054 grm.	12
0.055 - 0.064 ,,	38
0.065 - 0.074 ,,	112
0.075 - 0.084 ,,	212
0.085 - 0.094 ,,	281
0.095 - 0.104 ,,	252
0.105 - 0.114 ,,	227
0.115 - 0.124 ,,	101
0.125 - 0.134 ,,	48
0.135 - 0.144 ,,	17
0.145 - 0.154 ,,	5
0.155 - 0.164 ,,	3

Each class was placed in a separate breeding box, the males being kept in similar conditions.

As the range of pupa weights in the total sample was small, and the extremes of weight poorly represented, three classes were chosen, namely 0.065—0.074, 0.085—0.094, and 0.115 and 0.124, for use in the main experiment. It was intended that single females from each class hatching on the same day should be set up in separate cages, each with two males, and their production of eggs noted; throughout the test the insects were provided with pine twigs. As the experiment progressed, however, it was found that perhaps one of the selected weight classes would not be represented in the day's hatch, and a female from a neighbouring class was therefore substituted. Daily inspections were not made in order to keep disturbance of the ovipositing female to a minimum. At first, two-day-old males were used on the off-chance that a short period might be needed for maturation, but later on, when males were in short supply, freshly hatched ones were successfully used.

A supplementary experiment was carried out at the same time as the above, in order to provide data on pupae with extreme weights, and so that advantage could be taken of all females emerging from the weighed pupae. In this experiment any female emerging from any class was placed in a glass jar together with two males; her production was noted as before.

On death the females were opened and their ovaries examined. The ovaries containing the eggs may be divided into three regions:

(1) Portion with mature eggs
(2) Portion with a diminishing size series of developing eggs
(3) Portion where individual eggs can no longer be distinguished, but where there is only a mass of colourless cells.

The mature eggs can be distinguished by the fact that they are green, full size, hard-shelled and otherwise indistinguishable from those already laid. The developing eggs in the second region have no hard shell, but the individual eggs have the green colour until the smallest sizes are reached, when it disappears. As there is no sharp division between the second and third regions, it is at the point where the green colour disappears that counting of immature eggs was stopped.

After examination, the egg-laying capacity of a female was described as:

(1) Experimental Fecundity—that number of eggs actually laid in the experiment.
(2) Probable Fecundity—the Experimental Fecundity plus those eggs counted as mature in the ovaries.
(3) Possible Fecundity—Probable Fecundity plus all those eggs counted as immature.

The choice of the above terms needs some explanation. If the results of other workers are examined (Table 55) it will be found that, like ourselves, they failed

Table 55

Fecundity of Bupalus piniarius Females

	Stahl	Subklew		Forestry Commission	
	Lab.	Lab.	Forest	Lab.	Forest
Numbers of females examined	178	250	500	86	5
Experimental Fecundity (Average)....	73	147	—	73	—
Mature Eggs in Ovary (Average)	125	22	2	19	2
Immature Eggs in Ovary (Average)	54	—	12	12	—
Percentage of unlaid mature eggs.	63	13*	—	21	—

Note. * This percentage is of both mature and immature eggs together.

in some way to provide conditions for *B.piniarius* females to oviposit as successfully as they do normally in the field—as judged by the number of mature eggs still left in the ovary at death. Thus we term the number of eggs actually laid in the experiment the "Experimental Fecundity", because it is unrelated to anything but the experiment. The so-called "Probable Fecundity" approximates, in the opinion of the authors, to the actual field fecundity. Eidmann (1931), after close experiment, concluded that all eggs which are to mature have done so within three days of hatching. Subklew (1939) found that, after death, field-collected females had only two or three eggs left in the ovary, and this is consistent with the few specimens we were able to examine. It is with these two facts in mind that we have made the assumption that the actual field fecundity, or "Probable Fecundity" would be the Experimental Fecundity plus the mature eggs in the ovary. Figures for Possible Fecundity are included, as other authors have used this measure and it may therefore be useful for comparative purposes.

Discussion

The main experiment extended over sixteen days and fourteen females were used in each of the three weight classes (Table 56).

Actual Means and Standard Deviations Calculated From Main Experiment

Table 56

Weight Class of Pupae in Gms.	Actual Mean Weight (gms.)	Number in Class	Exper. Fecundity		Prob. Fecundity		Poss. Fecundity	
			Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
0.065-0.084	0.076	14	29	19	45	16	53	16
0.085-0.104	0.092	14	45	23	68	15	85	21
0.115-0.134	0.121	14	99	35	115	35	130	33

Analysis of the results of this experiment showed that, within the limits of the experimental error, the day of hatching had no effect on the fecundity of the females, and that the regression of fecundity on pupal weight did not depart significantly from linearity.

The data from the supplementary experiment represents an additional 46 individuals, the total duration of the experiment being about five weeks. The regressions calculated for the data of the main experiment and for all the data lumped together were approximately in agreement. The equation based on all the data for Probable Fecundity was:

$$N_{pr} = 14.6w - 63 \quad \ldots\ldots\ldots\ldots \quad (1)$$

[where N_{pr} = Probable Fecundity (number of mature eggs)]

similarly the equations for Experimental Fecundity, Ne, and the Possible Fecundity, Nps, would be:

$$N_e = 14.4w - 79 \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\text{and } N_{ps} = 14.6w - 51 \quad \ldots\ldots\ldots\ldots \quad (3)$$

(where w = pupal weight in hundredths of a gramme)

In Table 54 are given the correlation and regression co-efficients based on the lumped data.

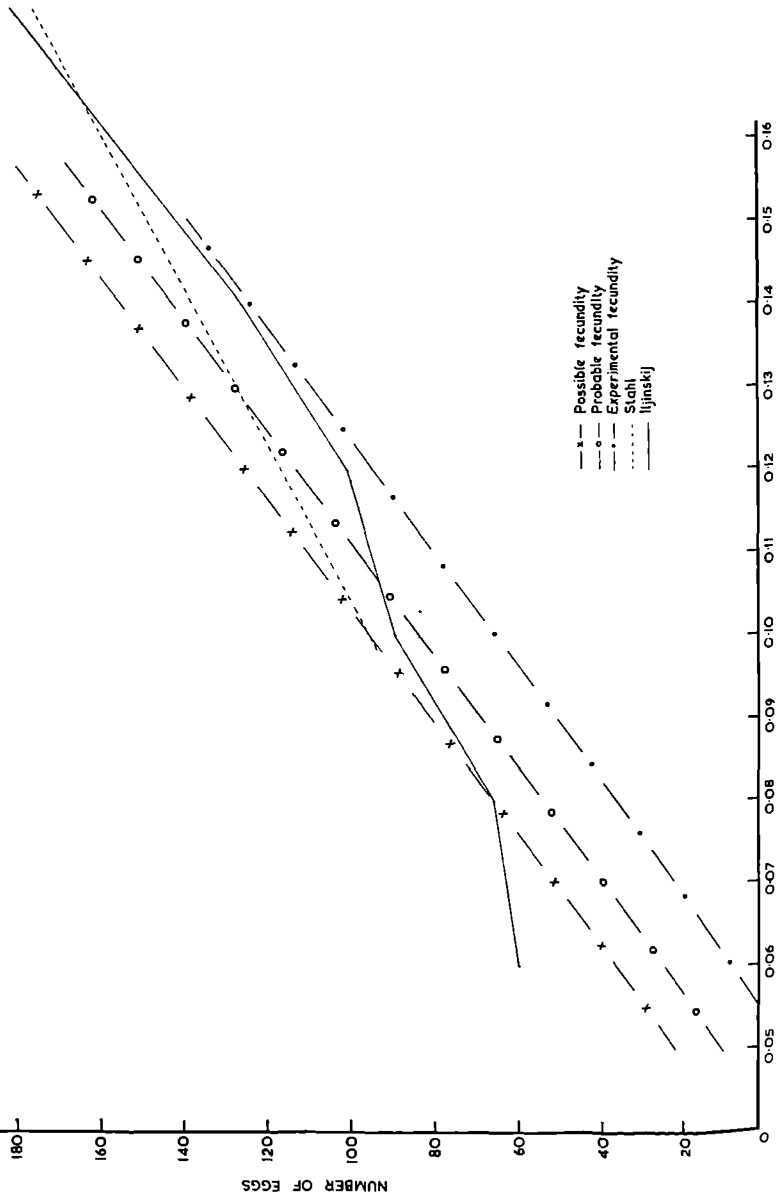


FIG. 8. Regression of Fecundity of Bupalus piniarius on Pupal Weight, 1955.

Correlation and Regression Co-efficients

Table 57

	Correlation Coefficient	Regression Coefficient	Standard Error of Reg. Coeff.
Experimental Fecundity	0.732	14.4	$\pm$ 1.46
Probable Fecundity	0.858	14.6	$\pm$ 0.96
Possible Fecundity	0.834	14.6	$\pm$ 1.06

The regression co-efficients express the increase in number of eggs corresponding to an increase in pupal weight of 0.01 gms.

The regression lines for Experimental, Probable and Possible Fecundity have been drawn, and superimposed on these will be found the results of Stahl's and Iljinskij's experiments (Fig. 8). Both workers used a rather different and wider range of pupal weights than we did; Iljinskij gives a fecundity of 245 for a pupal weight of 0.24 gms. and Stahl has weights up to 0.175 gms. and highest fecundity of 175.

One other point of interest has arisen from examination of the data. Calculation of the standard deviation for the main experiment, in which approximately equal numbers of pupae were taken in each size-class, suggests that use of the analysis of variance, and calculation of the regression line, may not be strictly valid owing to the tendency of the standard deviation of the number of eggs to increase with pupal weight. Transformation of both variables by their logarithms would overcome this difficulty and would permit a valid analysis, and further, would suggest the test of the hypothesis.

$$n = kw^m$$

(where n = number of eggs, k and m are constants, w = weight)

Data for probable fecundity was used for the test, and it was found that there was no appreciable departure from this hypothesis. The equation found was

$$n = 95.30\ w^{2.11} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

(where w is measured in milligrammes, and m differed from 2 by less than its standard error ($\pm$ 0.22).)

It is felt that perhaps where a more complete range of weights of pupae are dealt with, further consideration of the above hypothesis may be of interest. The regression lines derived by the two methods differed little and, for estimation of fecundity in practice the first equation is more easily calculated and therefore to be preferred.

Table 58 *Data from Main Experiment on Fertility of Bupalus piniarius*

Ref. No. (1)	Weight gms. (2)	Date of Hatch (3)	Total No. of Eggs Laid (4)	Mature in Ovary (5)	Mature + Laid (4+5)	Immature in Ovary (6)	Total (4+5+6)	Fertile * (7)	Duration of Life in Days (8)
1	0.07	24:5:55	0	24	24	5	29	No	10
2	0.09	,,	49	0	49	2	51	Yes	10
3	0.12	,,	111	7	118	3	121	Yes	11
4	0.08	,,	60	17	77	1	78	Yes	11
5	0.09	,,	52	14	66	0	66	Yes	10
6	0.12	,,	41	76	117	8	125	No	6
7	0.08	,,	35	5	40	1	41	Yes	9
8	0.09	,,	67	0	67	2	69	Yes	10
9	0.13	,,	128	5	133	5	138	Yes	10
10	0.07	27 : 5	1	21	22	4	26	No	9
11	0.09	,,	54	18	72	11	83	Yes	5
12	0.12	,,	79	1	80	12	92	Yes	12
13	0.08	,,	63	4	67	3	70	Yes	10
14	0.09	,,	0	92	92	30	122	No	13
15	0.12	,,	155	3	158	28	186	Yes	13
16	0.08	,,	10	24	34	7	41	No	10
17	0.10	,,	73	24	97	16	113	Yes	9
18	0.12	,,	125	27	152	10	162	Yes	9
19	0.08	28 : 5	20	21	41	18	59	Yes	10
20	0.09	,,	56	0	56	15	71	Yes	10
21	0.12	,,	117	3	120	21	141	Yes	9
22	0.08	,,	38	2	40	6	46	Yes	9
23	0.10	,,	64	5	69	29	98	Yes	9
24	0.12	,,	39	3	42	34	76	Yes	10
25	0.07	31 : 5	56	4	60	16	76	Yes	9
26	0.09	,,	0	55	55	66	121	No	7
27	0.12	,,	114	14	128	38	166	Yes	8
28	0.07	2 : 6	53	3	56	7	63	Yes	9
29	0.09	,,	67	7	74	5	79	Yes	12
30	0.12	,,	104	14	118	5	123	Yes	12
31	0.08	3 : 6	33	18	51	7	58	Yes	10
32	0.09	,,	65	4	69	18	87	Yes	11
33	0.12	,,	77	26	103	4	107	Yes	11
34	0.08	4 : 6	0	35	35	32	67	No	10
35	0.10	,,	76	10	86	2	88	Yes	9
36	0.12	,,	120	11	131	6	137	Yes	5
37	0.08	5 : 6	19	32	51	3	54	Yes	10
38	0.09	,,	1	59	60	14	74	Yes	10
39	0.12	,,	110	33	143	14	157	Yes	9
40	0.07	8 : 6	13	13	26	5	31	No	12
41	0.09	,,	0	46	46	21	67	No	12
42	0.12	,,	66	6	72	13	85	Yes	12

* Females were assumed to have been fertilized if they produced eggs from which caterpillars hatch. Copulation when observed was also noted.

Table 59 *Data from Subsidiary Experiment on Bupalus piniarius*

Ref. No. (1)	Weight gms. (2)	Date of Hatch (3)	Total No. of Eggs Laid (4)	Mature in Ovary (5)	Mature + Laid (4+5)	Immature in Ovary (6)	Total (4+5+6)	Fertile (7)	Duration of Life in Days (8)
1	0.13	9:5:55	45	52	97	2	99	Yes	14
2	0.14	,,	79	13	92	4	96	Yes	12
3	0.16	22 : 5	102	6	108	2	110	Yes	11
4	0.08	26 : 5	25	4	29	3	32	Yes	8
5	0.12	26 : 5	103	3	106	15	121	Yes	11
6	0.07	9 : 6	0	36	36	2	38	No	11
7	0.09	,,	63	8	71	3	74	Yes	11
8	0.12	,,	93	4	97	21	118	Yes	11
9	0.13	25 : 5	122	9	131	13	144	Yes	10
10	0.14	24 : 5	15	143	158	3	161	Yes	10
11	0.14	,,	161	4	165	11	176	Yes	11
12	0.14	,,	179	6	185	1	186	Yes	12
13	0.13	,,	113	24	137	8	145	Yes	8
14	0.13	,,	141	0	141	6	147	Yes	13
15	0.13*	,,	0	113	113	6	119	No	11
16	0.10	25 : 5	102	3	105	11	116	Yes	13
17	0.10	,,	102	8	110	0	110	Yes	10
18	0.13	,,	134	3	137	9	146	Yes	12
19	0.13	,,	139	4	143	22	165	Yes	12
20	0.11	,,	84	7	91	7	98	Yes	9
21	0.11	,,	10	72	82	3	85	Yes	7
22	0.11	,,	52	59	111	3	114	Yes	7
23	0.11	,,	73	10	83	3	86	Yes	7
24	0.12	,,	131	1	132	3	135	Yes	12
25	0.12	,,	115	4	119	8	127	Yes	12
26	0.09	,,	80	0	80	15	95	Yes	13
27	0.09	,,	91	1	92	62	154	Yes	14
28	0.13	26 : 5	205	1	206	12	218	Yes	12
29	0.11	,,	96	9	105	21	126	Yes	10
30	0.15	28 : 5	112	23	135	13	148	Yes	7
31	0.15	,,	142	5	147	28	175	Yes	11
32	0.08	,,	17	28	45	12	57	No	12
33	0.08	,,	15	19	34	23	57	No	4
34	0.05	2 : 6	0	9	9	29	38	No	9
35	0.14	5 : 6	104	30	134	21	155	Yes	9
36	0.15	6 : 6	153	2	155	26	181	Yes	13
37	0.15	7 : 6	203	3	206	9	215	Yes	11
38	0.07	8 : 6	59	0	59	6	65	Yes	11
39	0.07	,,	49	1	50	8	58	Yes	11
40	0.07	,,	0	40	40	6	46	No	11
41	0.14	,,	140	5	145	9	154	Yes	12
42	0.16	9 : 6	183	4	187	7	194	Yes	10
43	0.07	10 : 6	52	2	54	11	65	Yes	9
44	0.07	15 : 6	0	2	42	10	52	No	5

* Copulation was observed in one case (No. 15, Subsidiary Expt.) but no eggs were laid.

Summary

(1) An experiment was set up to determine the correlation between weight of female pupa and fecundity of the emerged adult.

(2) The terms Experimental, Probable and Possible Fecundity are defined, and it is felt that Probable Fecundity approaches most closely to actual field fecundity.

(3) Results are comparable with those of other workers, and provide an extension of the correlation to cover our lower range of pupal weights.

(4) Regression lines are drawn upon the diagrams and correlation and regression co-efficients calculated. Owing to a tendency for the standard deviation of the number of eggs laid to increase with pupal weight, an alternative method of dealing with the data is suggested and may prove useful where a greater range of pupal weights is involved.

REFERENCES

Eidmann, H. (1931) *Morphologische und Physiologische Untersuchungen der Weiblichen Genitalapparat der Lepidopteren.*

Engel, H. (1942) Uber die Populationsbewegung des Kiefernspanner (*B. piniarius*, L.) in verschieden Bestandstypen. *Z. Ang. Ent.* 29, pp. 116-163.

Escherich, K. (1931) *Die Forstinsekten Mitteleuropas* B. III, pp. 457-569.

Iljinskij, A. (1938) .... Concerning an approaching outbreak of *Bupalus piniarius* and *Panolis flammea* (in Russian). *W. Zaschitu lesa*, 5, pp. 34-41.

,, ,, (1941) *Instructions for the routine survey of outbreaks of forest Devoliators* (in Russian)—State edition, pp. 1-64.

Stahl, G. (1939) Ueber die Beziehungen Zwischen Puppendurchmesser, Puppengewicht, Puppenvolum und Eizahl beim Kiefernspanner *Bupalus piniarius*, L. *Die Kiefernspanner*, 1937, pp. 113-123, Hanover.

Subklew, W. (1939) Untersuchungen über die Bevölkerungsbewegung des Kiefernspanners, *Bupalus piniarius*, L. *Die Kiefernspanner*, 1937, pp. 10-50.

LOSS OF WEIGHT OF SMALL-SIZED HARDWOODS DUE TO DRYING

By E. G. RICHARDS

812.3:847.1

DURING THE SRRING and summer of 1955, an experiment was carried out in the Forest of Dean to determine the loss in weight due to drying of small unbarked spring-felled hardwoods when stacked in the forest for two months after felling. Stacks of oak, ash, beech, birch, sweet chestnut, sycamore and elm were weighed on the day of felling and at fortnightly intervals from May to July. Comparisons were also made between the weight of bark on unseasoned, and on partially seasoned spring-felled oak.

In May sufficient trees of each species were felled to give the produce set out in Table 60.

Table 60 *Produce used in Experiment*

Species	Diam. under bark Inches	No. of pieces 6 ft. 6 ins. long	Peeled or Not
Oak	2—3	25	Unpeeled
Oak	4—6	25	Peeled on day of felling
Oak	4—6	25	Peeled 10 weeks after felling
Oak	6—8	25	Unpeeled
Ash Beech Birch Sweet Chestnut Sycamore .... Elm	4—6	25 (each species)	Unpeeled

On the day of felling, the trees were cross-cut into the appropriate sizes and each piece weighed. In oak, twenty-five of the four to six inch diameter pieces were weighed, peeled, and immediately reweighed. The 6 foot 6 inch lengths were made into ten cross-piled stacks, i.e. one per species, size of produce or treatment. Each stack contained five layers, each of five pieces, the bottom layer of each stack being raised from the ground on wooden bearers.

During the cross-cutting, sample discs (five per stack) were cut adjacent to the ends of the 6 foot 6 inch lengths. The moisture content of these sample discs was then calculated from the formula:

$$\text{Fresh felled Moisture Content Percentage} = \frac{\text{Weight at time of cutting—Oven dry weight}}{\text{Oven dry weight}} \times 100$$

The stacks were reweighed at fortnightly intervals for eight weeks, care being taken to ensure that throughout the experiment each piece occupied the same relative position in the stack.

On the tenth week after felling the four to six inch diameter unpeeled oak was weighed, peeled and reweighed, in order to obtain the weight of partially seasoned bark.

The weather was exceptionally wet during May and June, with temperatures somewhat below average, and exceptionally dry from July to September with temperatures above average, as the data from Nagshead Crop Weather Station given in Table 61 show.

The loss in weight due to drying is given in Table 62. Loss in weight is expressed as a percentage of fresh-felled peeled weight for Stack 1, and fresh-felled unpeeled weight for Stacks 2 to 10.

It will be seen that in the first month after felling the unpeeled stacks had lost up to 5 per cent of their unpeeled fresh-felled weight; the oak peeled on the day of felling had lost 13 per cent of its peeled, fresh-felled weight.

Mean Monthly Air Temperatures and Average Monthly Rainfall.
May—September 1955

Table 61

Month		(A) Monthly Mean Air Temperature (° F.)	(B) Average Monthly Mean Air Temperature (° F.)	(A) as percentage of (B)	(C) Monthly Rainfall (ins.)	(D) Average Monthly Rainfall (ins.)	(C) as percentage of (D)
May	1955	49.1	51.7	94.9	6.31	2.5	252.4
June	1955	56.3	57.1	98.7	4.66	2.8	166.4
July	1955	63.1	60.1	104.9	0.16	2.9	5.5
August	1955	64.1	59.3	108.0	0.57	3.7	15.4
September	1955	56.3	55.5	101.4	1.28	2.7	47.4

Note: Data extracted from records of Nagshead Crop Weather Station and Climatic Normals (Provisional) BF/117/M.O. 19, dated 19/1/56.

At the end of the eighth week after felling all unpeeled species except ash and sycamore had lost more than 5 per cent of their fresh-felled unpeeled weight, but none had lost more than 10 per cent. The peeled oak in Stack 1 lost 17 per cent of its fresh-felled peeled weight in the same period.

Loss in Weight as a Percentage of Fresh-felled Weight

Table 62

Stack No.	Diameter Ins. U.B.	Species	Felled	Percentage of Loss in Weight: Number of Weeks after Felling 2	4	6	8
1	4–6	Oak (peeled)	4/5	9.3	13.3	13.8	16.6
2	2–3	Oak	5/5	(+1.9)	(+1.7)	2.6	6.0
3	4–6	Oak	4/5	0.3	2.5	3.8	5.5
4	6–8	Oak	4/5	1.3	2.7	3.8	5.4
5	4–6	Ash	16/5	2.5	1.3	3.6	4.3
6	4–6	Beech	16/5	0.9	2.9	5.2	6.6
7	4–6	Birch	16/5	2.5	3.1	4.5	6.7
8	4–6	S. Chestnut	18/5	4.4	5.1	7.9	9.7
9	4–6	Sycamore	18/5	0.2	(+0.2)	1.7	3.5
10	4–6	Elm	18/5	2.1	3.3	5.1	7.7

A statistical analysis of these figures showed that the losses in weight, expressed as a percentage of original weight, of unpeeled oak, beech, birch and elm, eight weeks after felling, were not significantly different; but that, by comparison with these species, ash lost weight more slowly and chestnut more quickly. The behaviour of sycamore during the first eight weeks, and of the two to three inch diameter oak in the first month, was anomalous, and could not be explained on the limited amount of data available.

The opportunity was taken to weigh the stacks on the 26th September before they were sold, i.e. about twenty weeks after felling. Ash had lost 8 per cent of its unpeeled weight, sweet chestnut 21 per cent, and the remaining unpeeled treatments between 14 and 17 per cent. The oak in Stacks 1 and 3 had lost 35 and 33 per cent respectively of their *unpeeled* fresh-felled weights: these losses were due to removal of bark (at different times) and drying.

Over the whole experiment the loss of weight was greater for the top layers of each stack than the bottom layers, both in the first few weeks when the weather was wet and in the dry period July to September.

Moisture contents of the various piles are given in Table 63 for the day of felling, eight weeks after felling, and the end of September, some 20 weeks after felling.

Moisture Content as a Percentage of Oven-dry Weight

Table 63

Stack No.	Diameter Ins. U.B.	Species	Moisture Content Percentage		
			On day of felling	After 8 weeks	On 26th Sept.
1	4–6	Oak (Peeled)	79	50	35
2	2–3	Oak	75	65	45
3	4–6	Oak	79	70	—
4	6–8	Oak	85	75	58
5	4–6	Ash	48	42	36
6	4–6	Beech	88	76	57
7	4–6	Birch	72	61	45
8	4–6	Sweet Chestnut	95	77	55
9	4–6	Sycamore	55	50	32
10	4–6	Elm	71	58	43

The moisture content eight weeks after felling and on 26th September were calculated from the formulas:

$$\text{Oven dry weight of stack} = \frac{\text{Weight on day of felling}}{\left(1 + \frac{\text{M.C.}}{100}\right)}$$

where M.C. = Moisture Content percentage on day of felling.

$$\text{Moisture content at time t} = \frac{\begin{array}{c}\text{Weight of stack} \\ \text{at time t}\end{array} - \begin{array}{c}\text{Oven dry} \\ \text{weight}\end{array}}{\text{Oven dry weight}} \times 100$$

The calculation is not precise in the case of unbarked wood, because it assumes that initially the percentage moisture content of bark is the same as that of wood, and that bark loses moisture at the same rate as the wood. However, the figures do demonstrate the order of the moisture contents in the stacks measured.

Initial fresh-felled moisture contents were in line with those obtained from other experiments (C.D. Begley and J. N. R. Jeffers, *Report on Forest Research, March 1955*, page 112). None of the stacks had reached the air-dry condition (17-23 per cent M.C.) by 26th September.

The loss in weight due to peeling the fresh-felled and partially seasoned oak is given below:

Weight of fresh bark as a percentage of fresh-felled over-bark weight:	13.6	± 0.708
Weight of partially seasoned bark as a percentage of over-bark weight, ten weeks after felling	10.7	

These figures do not of course represent the weight of bark since they are percentages of the weight of bark plus wood measured at different times. They do, however, form an estimate of the change in *relative* weights of bark and wood after ten weeks of seasoning under the conditions prevailing at the time of the experiment, and have statistical significance.

The experiment will be repeated in 1956, and having regard to the vagaries of our climate it would be unwise to draw too general conclusions from the results of the limited work done hitherto. The most that can be said is that small sized unpeeled hardwoods felled in May and stacked in open piles in the forest:

(1) Lost up to 5 per cent of their fresh-felled weight one month after felling (a wet period).

(2) Lost 5 to 10 per cent of their fresh-felled weight two months after felling (the weather becoming drier in the second month); and

(3) Lost up to 20 per cent of their fresh-felled weight by the end of the summer (an exceptionally dry July, August and September).

APPENDIX I

List of Main Experimental Projects and the Localities where Work is Concentrated

While most of the investigations and experiments of the Research Branch are scattered throughout forests all over the country, there are certain areas where work on some projects is more or less concentrated. These are briefly given below:

NURSERY EXPERIMENTS. Including partial sterilisation of the soil, maintenance of fertility, compost and fertiliser experiments, green cropping, chemical weed control, etc.

Inchnacardoch Forest Nursery, near Fort Augustus
Newton Nursery, near Elgin
Benmore Forest Nursery, near Dunoon
Tulliallan Nursery, near Alloa
Devilla Forest Nursery, near Alloa
Bush Nursery, near Edinburgh
Fleet Forest Nursery, Gatehouse of Fleet
Kennington Nursery, near Oxford
Sugar Hill Nursery, near Wareham

PLANTING EXPERIMENTS ON PEAT

Kielder Forest (Northumberland)
Clocaenog Forest (Denbighshire)
Beddgelert Forest (Caernarvonshire)
Inchnacardoch Forest (Inverness-shire)
Achnashellach Forest (Ross-shire)

PLANTING EXPERIMENTS ON HEATHLAND

Croft Pascoe Forest (Cornwall)
Wareham Forest (Dorset)
Wykeham and Broxa in Allerston and Langdale Forests (Yorks)
Harwood Dale in Langdale Forest (Yorkshire)
Teindland Forest (Morayshire)
Clashindarroch Forest (Aberdeenshire)

PLANTING EXPERIMENTS ON SAND DUNES

Newborough Forest (Anglesey)

PLANTING EXPERIMENTS ON CHALK DOWNLAND

Queen Elizabeth Forest (Buriton, Hants and Sussex)
Friston Forest (Sussex)

ESTABLISHMENT OF OAK

Forest of Dean (Gloucester, Hereford and Monmouth)
Dymock (Gloucester and Hereford)

POPLAR TRIALS AND SILVICULTURAL EXPERIMENTS

Harling, Thetford Forest (Norfolk)
Yardley Chase (Beds. and Northants)
Quantock Forest (Somerset)
Forest of Dean (Gloucester)
Hockham, Thetford Forest (Norfolk)
Wynyard (Durham)
Cannock (Stafford)
Doncaster (Yorkshire)
Dyfnant (Montgomeryshire)
Blandford (Dorset)
Stenton (East Lothian)

SPECIES PLOTS OR FOREST GARDENS

Bedgebury Forest (Kent)
Thetford Chase (Norfolk)
Beddgelert Forest (Caernarvonshire)
Benmore Forest (Argyll)
Crarae, near Minard, Argyll

GENETICS WORK. Grafting, propagating, etc.

Alice Holt Forest (Hants)
Grizedale Forest (Lancashire)
Bush Nursery (near Edinburgh)

EXPERIMENTAL SEED ORCHARDS

Rendlesham Forest (Suffolk)

PATHOLOGICAL RESEARCH AREAS

Moorburnhead (Dumfriess-shire)	Group dying of Conifers
Glenfinart (Argyll)	Group dying of Conifers
Haldon (Devon)	Resin bleeding of Douglas fir
Harling (Norfolk)	Fomes annosus
Mundford (Norfolk)	Bacterial canker of poplar
Queen Elizabeth Forest (Hampshire)	Wound Protectants

APPENDIX II

Staff of Research Branch as at 31st March, 1956

DIRECTORATE OF RESEARCH AND EDUCATION. 25, Savile Row, London, W.1. Tel.: Regent 0221.

J. Macdonald, C.B.E.	Director
Miss A. Brooks, M.B.E.	Senior Executive Officer

MACHINERY

R. G. Shaw, B.A., A.M.I.Mech.E.	Machinery Research Officer

UTILISATION DEVELOPMENT

E. G. Richards, B.Sc.	Divisional Officer
C. D. Begley, B.Sc....	District Officer
J. R. Aaron, M.A.	,, ,,

FOREST RESEARCH STATION. Alice Holt Lodge, Wrecclesham, Farnham, Surrey. Tel.: Bentley 2255.

M. V. Laurie, O.B.E., M.A., Dip.For.	Conservator, Chief Research Officer
E. C. Harper	Higher Executive Officer

SILVICULTURIST (SOUTH) (Alice Holt).

R. F. Wood, B.A., B.Sc.	Divisional Officer
M. Nimmo	District Officer
G. D. Holmes, B.Sc.	,, ,,
J. R. Aldhous, B.A.	,, ,,
A. D. S. Miller, B.Sc.	,, ,,
J. Jobling, B.Sc.	,, ,,
J. M. B. Brown, B.Sc., Dip.For.	,, ,,
W. H. Hinson, B.Sc., Ph.D.	Scientific Officer
G. Buszewicz, Mgr.Ing.	Experimental Officer

SILVICULTURIST (NORTH). Government Bulidings, Bankhead Avenue, Sighthill, Edinburgh, 11. Tel.: Craiglockhart 4010.

M. V. Edwards, M.A.	Divisional Officer
G. G. Stewart, B.Sc.	District Officer
R. Faulkner, B.Sc.	,, ,,
R. Lines, B.Sc.	,, ,,

MENSURATION AND CENSUS

F. C. Hummel, M.A., D.Phil.	Divisional Officer
A. M. Mackenzie (Stationed at Edinburgh)	District Officer
G. M. L. Locke, B.Sc.	,, ,,

FOREST PATHOLOGY

T. R. Peace, M.A.	Divisional Officer
J. S. Murray, B.Sc.	District Officer
S. Batko, D.Ing.	

FOREST ENTOMOLOGY

M. Crooke, B.Sc., Ph.D.	District Officer
D. Bevan, B.Sc.	,, ,,
Miss J. Davies, B.Sc.	Experimental Officer

FOREST GENETICS

J. D. Matthews, B.Sc.	District Officer
A. F. Mitchell, B.A., B.Ag.	,, ,,

DOCUMENTATION AND PHOTOGRAPHY

G. D. Kitchingman, M.A., Dip.For.	District Officer
I. A. Anderson	Principal Photographer
Miss T. K. Wood	Photographer

LIST OF PUBLICATIONS

The following papers by members of the Research Branch staff were published during the year ended 31st March, 1956:

AARON, J. R. Timber in River and Sea Defence Works. *Timber Technology* Vol. 63. No. 2197. (Nov. 1955).

BEGLEY, C. D. .... Seasoning Before Extraction; a Study of its Effect on Extraction Times *Rep. For. Research* (1955) H.M.S.O. pp. 106-111.

BEGLEY, C. D. and JEFFERS, J. N. R. Moisture Content of Fresh-felled Hardwoods. *Rep. For. Research* (1955) H.M.S.O. pp. 112-118.

EDWARDS, M. V. The Hybrid Larch—*Larix* x *eurolepis* Henry. "*Forestry*" Vol. 29. No. 1. (1956) pp. 29-43.

FAULKNER, R. A Note on Current and Recent Forest Nursery Research in Scotland. "*Arbor*" Vol. 2(5) (1955) pp. 33-35.

Comparison of Shell DD with Formalin as a Conifer Seedbed Partial Soil Sterilizer. *Rep.For.Research* (1955) H.M.S.O. pp. 94-101.

HOLMES, G. D. .... Experiments in the Poisoning of Standing Trees to Facilitate Bark Peeling of Felled Logs. *Rep.For.Research* (1955) H.M.S.O. pp. 119-26.

HOLMES, G. D. and BUSZEWICZ, G. Longevity of Acorns with Several Storage Methods. *Rep. For. Research* (1955) pp. 88-94.

HUMMEL, Dr. F. C. Die Massengerade als Grundlage von Einheitstarifen für den Alterklassenwald. *Forstwissenschaftliches Centralblatt* Vol. 75. March-April, 1956.

The possibilities of wider espacements and shorter rotations for conifer plantations in Great Britain. *J. of Oxford Univ. For. Soc.* (1956).

JEFFERS, J. N. R. Barr and Stroud Dendrometer, Type F.P.7. *Rep. For. Research* (1955). H.M.S.O. pp. 127-136.

JOBLING, J. Farm and Forest: Cultivation of Poplars. *Agriculture.* Vol. LXII. No. 4, pp. 89-90. July 1955.

Farm and Forest: Raising Poplars. *Agriculture.* Vol. LXII. No. 5, pp. 240-241. August 1955.

KIRKLAND, R. C. and STYLES, J. H. Notes on *Pristiphora glauca* Bens. *Bulletin Ent. Res.* Vol. 46 Pt. 4. (1956) pp. 749-52.

MACDONALD, J. Notes on Forestry in Sicily. *Forestry.* Vol. 28. No. 2 (1955), pp. 81-93.

MATTHEWS, J. D. The Influence of Weather on the Frequency of Beech Mast Years in England. *Forestry* Vol. 28. No. 2. (1955), pp. 107-116.

MITCHELL, A. F. The Selection of "Plus" European Larch Trees. *Scottish Forestry* Vol. 10 No. 2. (1956) pp. 68-80.

MURRAY, J. S. Rhizina inflata associated with Group Dying of Conifers in Britain. *Plant Protection Bulletin.* Vol. 4. No. 1. October 1955. F.A.O. Rome.

MURRAY, J. S. *Rusts of British Forest Trees.* F. C. Booklet No. 4. H.M.S.O. (1955).

MURRAY, J. S., and YOUNG, C. W. T. The effect of brashing and thinning debris on the incidence of Lophodermium pinastri. *Quarterly Journal of Forestry.* Vol. L. No. 1. pp. 75-76. January 1956.

PEACE, T. R. Sooty-bark disease of Sycamore—a disease in eclipse. *Quarterly Journal of Forestry.* Vol. XLIX. No. 3. pp. 197-204. July 1955.

WOOD, R. F. Studies of North-West American Forests in Relation to Silviculture in Great Britain. *F.C. Bulletin* No. 25. H.M.S.O. (1955).

WOOD, R. F. and THIRGOOD, J. V. Tree Planting on Colliery Spoil Heaps. *Colliery Engineering* Vol. 32. Dec. 1955. and Vol. 33. Jan. 1956.

WOOD, R. F. and THOMPSON, J. H. *Cupressus macrocarpa* Plantations at Cumlodden, Argyll. *Quart. J. For.* Vol. 49. No. 2. (1955).

WOOD, R. F. and WESTALL, A. W. *Guide to the National Pinetum and Forest Plots at Bedgebury.* Second Edition (1956) H.M.S.O.

YEATMAN, C. W. *Tree Root Development on Uplands Heaths.* F. C. Bulletin No. 21. (1955) H.M.S.O.

ZEHETMAYR, J. W. L. and FARQUHAR, J. Pruning of Conifers by Disbudding. *Rep. For. Research* (1955) H.M.S.O. pp. 102-106.

The following Forestry Commission Leaflets were revised or prepared by members of the Research Branch staff:

Oak Leaf Roller Moth	No. 10
Felted Beech Coccus	,, 15
Watermark Disease of the Cricket Bat Willow	,, 20
Leaf Cast of Larch	,, 21
Collection and Storage of Ash, Sycamore and Maple Seed	,, 33
Pine Sawflies	,, 35

Printed in Great Britain under the authority of Her Majesty's Stationery Office
by Joseph Wones Ltd., West Bromwich

(3845) Wt.3751/2337 K24 1/57 J.W.Ltd. Gp.517

FORESTRY COMMISSION

REPORT
ON FOREST RESEARCH
for the year ended
March, 1957

LONDON
HER MAJESTY'S STATIONERY OFFICE
1957

PART III

REPORTS ON RESULTS OF INDIVIDUAL INVESTIGATIONS

INTRODUCTION

By JAMES MACDONALD

Director, Research and Education

It is with regret that we mention the death of Sir William Wright Smith, Regius Professor of Botany in the University of Edinburgh, who had been a member of the Commission's Advisory Committee on Forest Research since its establishment in 1929. During that long period, Sir William had given valuable service and his experience and wise counsel will be greatly missed.

Changes in staff during the year under review have not been numerous, but it has been possible to strengthen the staff of the new management section by the transfer to it of two officers, Mr. D. R. Johnston and Mr. A. J. Grayson, who had been serving under the Director of Forestry for England. Mr. J. N. R. Jeffers, who had left the Commission's service the previous year, returned and was given charge of a section dealing with statistics and design of experiments, in which he is responsible to the Chief Research Officer. Mr. E. C. Harper, Chief Clerk at Alice Holt, transferred to another branch, and was succeeded by Mr. R. Rendle.

Work on the extension to the Research Station at Alice Holt started at the beginning of December, 1956, and will be completed by about the end of 1958. The new structure, which consists of a wing, three storeys high, extending outwards from the old buildings of Alice Holt Lodge, should give adequate accommodation.

The twelfth Congress of the International Union of Forest Research Organisations took place at Oxford from July 6th to July 13th, 1956 and was attended by about 250 delegates from member-institutes in more than 40 countries. The Congress which was opened by the Minister of Agriculture, Fisheries and Food, the Right Honourable D. Heathcoat Amory, held its meetings in the Imperial Forestry Institute, kindly made available by the University of Oxford. The Congress involved our research officers in much additional work which was cheerfully undertaken and it imposed a heavy burden on Professor Sir Harry Champion and his staff at Oxford who contributed greatly to its success. At the end of the Congress, the Director was elected President of the Union and will hold office until after the next Congress which is due to be held in Vienna in 1961. During the Congress, visits were paid to the Forest Products Research Laboratory at Princes Risborough, to Rothamsted Experimental Station and to our Research Station at Alice Holt. The Congress itself was followed by a series of study tours, running concurrently in different parts of the country. These attracted a considerable number of delegates.

The Research Station at Alice Holt was inspected by the Forestry Commissioners in April, 1956 when the Commissioners also visited the Imperial Forestry Institute and Kennington Nursery at Oxford. In June of that year, also, an important delegation from the Soviet Union paid a visit to the Research Station. During the year, there was a sharp increase in the number of visitors to Alice Holt, no fewer than 511 being received, including forest officers and others from Austria, Belgium, Canada, Chile, Denmark, Finland, Formosa, France, Germany, India, Iraq, Israel, Japan, Kenya, the Netherlands, Nigeria, North Borneo, Northern Rhodesia, Norway, Nyasaland, Poland, the Soviet Union, Spain, Sweden, Switzerland, Thailand, Turkey, Uganda, Uruguay, the United States of America and Yugoslavia.

Forestry students from Oxford, Edinburgh, Aberdeen and Bangor paid their usual visits, while other parties who arrived at Alice Holt included students from Guildford Grammar School, from University College, London, and from the Fabian Society's Summer Schools.

Experimental areas in various parts of the country were visited, not only by parties from the International Union of Forest Research Organisations but also by a considerable number of individual forest officers from different parts of the world. In addition, the forest gardens at Crarae and Benmore in Argyll were visited by the International Dendrological Union, the peat planting experiments at Kirroughtree, Kirkcudbrightshire by the Scottish Peat and Land Development Association, and the experiments at Drummond Hill, Perthshire by the Society of Foresters of Great Britain. Students from the Universities of Aberdeen, Birmingham, Edinburgh and Manchester also visited experimental areas in various forests, while a party of forestry students from Sweden were shown some of our research work in Scotland.

The Director and Dr. F. C. Hummel visited the Soviet Union as members of a delegation from the Forestry Commission which visited that country in August and September, 1956. Mr. M. V. Laurie spent three weeks in East Africa where he represented the Colonial Office at a meeting of the East African Research Council and discussed forest research work in the three territories.

Colonel R. G. Shaw, Machinery Development Officer, and Mr. E. G. Richards were representatives of the United Kingdom on a joint F.A.O./E.C.E. working party on tractor testing which was held in Geneva in June, 1956, while Mr. G. D. Holmes and Mr. G. Buszewicz attended the Congress of the International Seed Testing Association, held the same month in Paris at which Mr. Holmes was elected Chairman of the Forest Seeds Committee of that Association.

Mr. T. R. Peace was present at a meeting of the International Poplar Commission in Brussels in July, and Mr. R. F. Wood attended a Colloquium in Paris dealing with the contribution of French botanists to the study of the North American Flora. In November, 1956, Mr. J. D. Matthews represented I.U.F.R.O. at the inaugural meeting of the International Commission for the Nomenclature of Cultivated Plants, which was held at Utrecht. Dr. M. Crooke, along with one of his foresters, Mr. R. Kirkland, visited forests in the neighbourhood of Nuremburg, to make further studies of the use of fogging machines against insect pests.

The Director spoke on Forest Research to the Royal Forestry Society of England and Wales in May, 1956. Mr. M. V. Laurie acted as chairman of the Forestry sub-section of the British Association at its meeting in Sheffield and delivered an address. Other members of the staff have given lectures at training courses at Northerwood House and elsewhere.

We are glad to report that Dr. M. Crooke has been awarded a Nuffield

Foundation Fellowship which will enable him to study forest insect conditions and methods of control in Canada for the greater part of a year.

The Advisory Committee on Forest Research held a meeting in September at Pitlochry when it reviewed part of the programme of research and visited several experimental areas in that district. Professor W. H. Pearsall, F.R.S., has recently been appointed a member of this Committee.

The sub-Committee on research into the Nutrition of Young Trees in the Nursery, met at Cardiff in October when it was able to examine and advise on the system of manuring in the Commission's large nursery at Tair Onen. Arrangements have now been made to start writing for publication the results of ten years' research work carried out by this sub-Committee.

The Advisory Committee on the Utilisation of Home-Grown Timber met twice during the year, once in London and once at Dunoon in Argyll where members visited the Ari-sawmill and were able to study problems of utilisation in rapidly developing forests.

Close co-operation has continued between the Commission and the Department of Scientific and Industrial Research, and an agreed programme of research in forest products has been worked out with the Director of the Forest Products Research Laboratory. The assistance given by this Department is greatly appreciated. In the field of utilisation, the Timber Development Association and the British Leather Research Manufacturers' Association have also given assistance, and we are indebted to the Directors of these Institutions for the help they have given.

As in other years, the Research Branch has worked in co-operation in a number of projects with Rothamsted Experimental Station, the Macaulay Institute for Soil Research and the Imperial Forestry Institute, Oxford, and acknowledgment is made of the great assistance given by these institutions. At the same time it has been possible to keep in touch with Nature Conservancy and with the Universities which are studying problems directly or indirectly connected with the forest.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE

Chief Research Officer

The Season

Perhaps the most outstanding feature of 1956 was the wet, cold and comparatively sunless summer which followed a very dry spring.

February was the second coldest of this century and was only just beaten by February 1947. The cold drying winds, coupled with the frost and snow of January and February caused widespread damage, not only to the less hardy trees and shrubs but also to Scots pine which shows more damage by severe winter cold than many of us would expect. These early cold winds, followed by severe spring droughts, caused many failures both in our nurseries and in newly planted forest areas, and made fire hazards very great.

The wet summer was bad for the spread of fungal diseases and damage by *Keithia* and *Lophodermium* was worse than usual. November was most unusually dry, with less than an inch of rain in parts of south and east England, while December was equally wet with over twice its normal rainfall in many places.

1957 started with an unusually mild but stormy January, and gale damage was reported fairly widely. February was mild and very wet. March was the mildest at Kew since records began there in 1871 and the third mildest in Scotland since their records started in 1856. Taking these three months together it was, in most places, the mildest opening to a year ever recorded.

PART I

This part of the Report deals with current work carried out by the various sections of the Forestry Commission's Research Branch. Only the more important items of work are mentioned in this summary.

Forest Tree Seed Investigations

GERMINATION TESTING. Routine testing took up the greater part of the time in the Seed Laboratory. When issuing test results, information on the number of viable seeds per pound of seed is now given, as this is a better guide to sowing density in the nursery than the plain germination percentage.

SEED STORAGE. Conifer seeds stored dry in sealed containers at a constant low temperature still show a high germination figure after seven years' storage. Intensive experimentation continues on the problem of storing beech seed. Methods of quickly determining the moisture content in large quantities of seed in store are being investigated.

SEED-BORNE FUNGI. Four more fungi have been found on conifer seeds in addition to the long list already reported. It is hoped to start testing the pathogenicity of these fungi on seeds next year.

Nursery Investigations

PARTIAL STERILIZATION. Although application of neat formalin to the surface of the soil was found much less effective than the standard method of watering with a diluted solution, it was found that drilling neat formalin gave almost as good results as the standard method. Mechanical injection of neat formalin or of chloropicrin into the soil also gave satisfactory results, and is cheaper than applications of diluted formalin solutions involving the transport of large quantities of water about the nursery. The search for cheaper sterilants continues.

NURSERY MANURING. Work on this project is, apart from a series of long-term fertility maintenance experiments, drawing to a close. Experiments with late and heavy applications of nitrogen fertilisers to Douglas fir and larch seed beds again failed to produce any increased susceptibility to damage by frost in the autumn. Alternative forms of nitrogen fertilisers, notably urea and ammonia gas, did not give as good results as "Nitrochalk" but, owing to the cold season, all responses to nitrogen were small.

AMELIORATION OF HEAVY SOILS. Treatment of heavy nursery soils by incorporating a 2-inch thick layer of powdered charcoal in the top 4 to 5 inches of the soil resulted in slightly better seedling crops, providing a contrast with the poor result noted in the previous year.

DATE OF SOWING. Oak and beech sowed in the autumn with an extra 4 to 6 inches depth of soil covering gave as good, but not better, results than normal spring sowing, provided the extra depth of cover was removed in the spring.

NURSERY TREATMENT OF ABIES. Experiments to improve the nursery technique for raising *Abies* spp., have so far indicated that stratification for two to three months before sowing improves germination, that autumn sowing can result in serious losses from frost, late March or April sowing being the best, and that a seedbed cover of a quarter to half an inch of grit gives the best seedling yields.

IRRIGATION OF NURSERY BEDS. Again, great increases in yields and in seedling growth were obtained in seed beds irrigated by an overhead spray line. Application of nitrogen fertilisers in solution through the spray line was less effective than equivalent amounts applied dry to the soil in the normal manner.

WEED CONTROL. A new material, "S.1112", was tested against the standard application of vaporising oil as a pre-emergence weed killer but proved less effective. Allyl alcohol, injected into the soil undiluted, was also less efficient than vaporising oil, though when diluted with water it gave better control than the oils. Two other chemicals—"C.D.A.A." and "C.D.E.C." are also under test. A chemical "S.776" was tested as a post-emergence weed killer, but was found, in the concentration tested, to damage the conifer seedlings. Tests with "C.M.U." as a complete weed killer on fallow land have shown that in doses of 200 grams and over per 100 square yards, some damage to crops raised in the following year may be expected, though Japanese larch appears to be more resistant than other species tried.

MALEIC HYDRAZIDE. Seedlings sprayed with this growth inhibitor, showed on being planted out a reduction in growth for at least two years.

PROTECTION AGAINST PESTS. Seeds treated with "Morkit" and "Indasco" as bird repellants, showed no reduction in yield by using "Morkit", but significant reduction when "Indasco" was used singly or in combination with "Morkit". No bird damage occurred in any plots including untreated controls. "Aldrex" and "Dieldrex" gave very effective control against cutworm attack.

HANDLING OF PLANTS. Polythene wrapping has again proved most successful for preserving plants in transit or in storage, high survivals on planting out (over 80 per cent) being obtained after four weeks' storage. Tests have included Corsican pine, normally a difficult species to handle. Four hours' exposure reduced survival to 50 per cent, but if plants were packed in polythene, no reduction in survival on planting was found after 56 hours' storage.

Silvicultural Investigations in the Forest—South and Central England and Wales

GROUND PREPARATION AND PLANTING METHODS. In south England and Wales, work has continued on ploughing methods. The deep tine plough is proving itself on southern heaths, particularly where the subsoil is compacted. The effect of different methods and intensities of ploughing on subsequent crop increment is the subject of a series of experiments. Trials with the "Lowther" planting machine continued in order to ascertain its possibilities and limitations. It was noticeably successful on unploughed or fully ploughed ground.

AFFORESTATION OF PARTICULAR TYPES OF LAND. Planting trials, started in 1954, on the exposed Lizard Peninsula on soils derived from serpentine rock, are encouraging. Given phosphate manuring and deep ploughing, Sitka spruce, *Pinus radiata* and coastal *Pinus contorta* have made a vigorous start. Trials on impoverished eocene sands at Wareham and Purbeck, with different methods of ploughing, manuring and different species continued, but it is too early to judge results. Similar work is continuing on mineral soils over shale in mid-Wales.

SPECIES TRIALS. Apart from the species tried out on special difficult sites mentioned above, *Nothofagus procera* and *N. obliqua* have been planted out on thirty sites covering a wide range of climates and soils. It is hoped thereby to get a clearer picture of the place, if any, these species might have in British forestry.

MIXTURE EXPERIMENTS. Following the pattern of the Sitka spruce/*Tsuga* mixtures planted in the previous year, experiments comparing pure and mixed plantings of Douglas fir and *Tsuga heterophylla* were planted on five sites in England, Scotland and Wales.

IMPROVEMENT OF CHECKED PLANTATIONS. Heavy phosphate manuring has brought 19-year-old checked Sitka spruce out of check at Wilsey Down, Cornwall. In checked pine crops at Wareham, Dorest, and Haldon, Devon, killing of heather with 2-4 D sprays has been successfully achieved without damage to the trees. It is too early to say whether the pines will respond to the removal of the heather competition.

MANURING OF POLE-STAGE CROPS. A start has been made on what promises to be a big project to ascertain whether worth-while improvements in rate of growth in older crops can be achieved by manuring.

CHEMICAL WEED CONTROL. Work continues on chemical methods of clearing fire traces of vegetation. Triochloracetic and borax compounds have shown the most promise so far. For the control of woody weed growth under forest conditions "2, 4, 5-T" has proved the most generally effective material. The economics of chemical weed control in the forest still need to be worked out.

PROTECTION OF SEEDS AND TREES AGAINST ANIMALS. For species which can be raised by direct sowing in the forest, protection from mice and other vermin is necessary. Experiments with a number of compounds have been carried out, but so far no really effective seed dressing has been found. The search for efficient substances for the protection of young trees against damage by deer and by voles continues.

Silvicultural Investigations in the Forest—Scotland and North England

AFFORESTATION PROBLEMS. Trials of species, methods of ploughing and the use of fertilisers have continued on heathland and peat land sites. On certain difficult sites, such as the smoky areas in the Pennines, an exposed sea coast site in Wester Ross, a peat bog at Spadeadam Forest, and part of the western end of the Moor of Rannoch, pilot plots of a number of species, planted in a matrix of *Pinus contorta*, have been established.

THINNING. An experiment to study the development of a Norway spruce crop under the form of heavy crown thinning now in use in South Scotland Conservancy, as compared with the standard practice of moderately heavy "low" thinnings (C/D grade), has been laid down.

ATMOSPHERIC POLLUTION. A series of pollution gauges have been established in the Pennines to endeavour to evaluate the smoke factor as affecting tree growth.

EXPOSURE. A technique for estimating the exposure factor on forest sites by measuring the rate of tattering of unhemmed flags has been developed, and useful, if rough, data on the degree of exposure has been obtained for a wide range of planting experiments. There is no doubt that in many places, exposure to wind overshadows all other factors affecting the growth of trees.

Derelict Woodland Investigations

An account is given of a range of machines and methods for clearing derelict woodlands, either completely or in strips, for planting. A specially developed "V-blade" cutter has given the most promising results, and is illustrated in Plate 1.

Provenance Studies

Work continues in finding the most suitable provenances of *Pinus contorta* and Sitka spruce for use in this country on various site types. The correct selection of *P. contorta* provenance appears to be particularly important. A study of first, second and third generation hybrid larch plantings 20 years old shows that the third generation is far slower than the second or first generations, but that, in this experiment, there is no clear difference in rate of growth between first and second generation hybrids. The issue is, however, complicated by other seed provenance factors. Results of a European larch provenance experiment. 19 years old, are reported, and in a later Welsh experiment planted in 1952. Polish larch gave the best height growth (apart from hybrid larch) and Munsterthal (Swiss Alps) larch the worst. Interim results of provenance trials of Corsican pine, *Pinus ponderosa* and Scots pine are also given.

Poplars

A large proportion of the work has been concerned with the planting and maintenance of trial plots and silvicultural experiments. Plots were laid down at five forests during the year, and seven experiments were planted. Planting of the populetum has continued, and a number of additions were made to the clonal collection. The testing of clones for resistance to bacterial canker by inoculation has been extended to a second nursery, and the scheme whereby clones in field trials can be tested for their natural resistance to the disease has been continued. Cuttings of the standard varieties were again distributed to the trade, private estates and other Forestry Commission nurseries, and cuttings of a number of non-standard varieties were supplied to research workers abroad.

Forest Ecology

The survey of the performance of Corsican pine throughout Britain in relation to climate and soil is almost complete. It seems likely that soil temperature in the rooting zone is one of the most important factors affecting the growth and health of this species in Britain. Studies on the influence of forest crops of oak, beech and Douglas fir on the air and soil temperature, as compared with a nearby open site under grass, are giving interesting results. Work continues on the factors affecting the survival and growth of beech regeneration in the Chilterns.

Forest Soils

The soils section has carried out a large number of determinations of the major nutrients in soils, ground water and conifer needles, mainly in connection with silvicultural investigations. A comprehensive survey of seedbed cover grit used throughout Britain has brought to light several cases of the use of unsuitable material. Sand culture techniques were used to obtain information on nutrient deficiency symptoms in poplars. A small beginning has been made on the major research project of the section, namely the nutrient relations of forest crops and forest sites.

Forest Genetics

Progress is reported on four major projects. The comprehensive Register of Seed Sources for Britain now contains 319 classified entries totalling 5,506 acres. The section provided data for the Scottish Forest Tree Seed Association who have compiled a Register of Seed Sources for their members.

The number of Plus trees which have been marked and recorded is now 2,062. Five hundred and sixty-four of these are Scots pine. Three hundred and sixty-four parent trees were propagated by grafting during spring of 1956, the total number of grafts attempted being 9,495. This is a smaller total than in past years, the reduction being due to the greatly increased pollination programme on the larches, Douglas fir and beech. The rooting of cuttings of Plus trees of *Thuja plicata* and other species, including X *Cupressocyparis leylandii*, was continued.

A total of 585 clones of Scots pine, the larches, Douglas fir and beech were planted on three sites where Tree Banks are being established. Work continued on seed orchards of Scots pine, European larch, Douglas fir and beech at eleven sites totalling 120 acres. Seed orchards composed of clones of European and Japanese larch are being planted to produce seed of the F1 hybrid larch, X *Larix eurolepis*. Work is in progress at five sites totalling twenty-eight acres. The seed orchard established in 1951 at Newton Nursery (Morayshire), for the production of hybrid larch seed, yielded just over one pound of seed per acre in 1956.

A promising technique for the propagation of cuttings of larch is now being followed up. The percentage success using summerwood cuttings in a sub-irrigated and heated frame has been increased to forty-eight per cent by the use of a sand and peat rooting medium, and the removal of the terminal half inch of the cuttings at the time of insertion.

Forest Pathology

The *Fomes annosus* project is now the most important in the pathological section, and has been considerably widened in scope. A survey of the status of *Fomes* in Britain has almost been completed. This has involved visiting all forests in Britain where infection has been reported, and assessing the need for protection. The survey data has brought out several important generalisations. It is apparent that the disease builds up slowly, the development to be measured in rotations rather than decades. In the first rotation, infections occur sporadically at a relatively late age of the crop, while in the second the plants are affected from the first. This is important, also, because the evidence shows that resistance to decay increases with age. In all observed cases, the infection has apparently come in via stumps, apart from rare instances where green brashing wounds were affected and where infection was traced to the use of fencing material cut from diseased timber.

A series of experiments has also been initiated on various aspects of *Fomes* control. Other experiments laid down are concerned with the development of *Fomes* under various conditions.

Work on "group dying" of conifers confirmed the hypothesis that the cause was "*Rhizina inflata*" attacking root systems after colonisation of fire sites.

Work on various other diseases was continued. Prominent among these are *Keithia thujina* on *Thuja*, *Ceratostomella ulmi* on elm, and *Botrytis cinerea*.

Probably the most notable occurrence from the pathological aspect was the widespread defoliation of young pine by *Lophodermium pinastri*. *Sclerophoma pithyophila* was also concerned. Most of the reports were made in late 1956 and early 1957 and constituted the largest single item of the section's minor queries. The 1956 season was abnormally wet and this probably had some bearing on the attacks.

Forest Entomology

Work on the pine looper, *Bupalus piniarius* L., has been continued. The pupal survey has shown either no change, or else a drop in population throughout Great Britain, with the single exception of Tentsmuir (Fife). Here counts are dangerously high in several compartments, and it is possible that control operations may have to be used. Population studies have now been carried on for a year in the study plot established last year in Elveden, Thetford. Sampling techniques are being evolved and accurate assessments of successive mortalities obtained. In the laboratory the correlation between fecundity and female pupal weight has been extended to the higher weights, and some studies into other aspects of the biology carried out.

A further trial of the "Tifa" fogging machine has given encouraging results. It is now felt that this machine can be of considerable value in forestry, particularly where the treatment of small areas would make aerial spraying uneconomic, or where the decision to control has had to be delayed.

This year preliminary studies were started on the parasites of *B. piniarius* at Elveden, Thetford, and in the laboratory. Egg assessments revealed an apparent erratic fluctuation of percentage parasitism. But analysis shows a positive correlation between percentage parasitism and host numbers. In the larval period, *Campoplex oxyacanthae* appeared, to the exclusion of *Heteropelma calcator*. The percentage parasitism of this species lies between 11.8 and 4.7 per cent. Throughout the year the pupal parasite *Cratichneumon nigritarius* was in low numbers in the field.

In the laboratory no work has been carried out on *Trichogramma* sp., but useful biological data has been compiled on *Campoplex oxyacanthae* and *Heteropelma calcator*. The parasite *C. nigritarius* has proved so far to be most difficult to study under insectary conditions.

Curculio elephas Gyll, the chestnut weevil, has again been imported in large quantities into this country, this time in acorns from Austria. Import restrictions are being arranged to prevent its establishment.

A brief account is given of the results of a series of experiments on the protection of newly formed conifer plantations against pine weevil (*Hylobius abietis* L.) attack, using the insecticides D.D.T., B.H.C., and dieldrin, at various dosage rates applied either as dips before planting or as sprays or dusts after planting. Almost all of the different treatments gave adequate levels of practical protection, and the choice of a standard method depends almost entirely on convenience and on cost. In general, dipping is to be preferred, and the most suitable material is considered to be 5 per cent D.D.T. solution. Spraying or dusting are useful treatments to give in cases where weevil attack develops unexpectedly but they are, of course, considerably more expensive than dipping. Spraying is probably more convenient than dusting, although the latter gives slightly better results, and a recommendation of a spray of 1 per cent D.D.T. at the rate of 50 cc. per plant is made.

Retreatment in the second season improves the amount of protection afforded, but not sufficiently greatly to make double treatment an economic proposition.

Forest Management

A new section dealing with Forest Management has now been formed. It includes the former Mensuration and Census section, together with two new sections dealing with Working Plans and Forest Economics.

WORKING PLANS. Work has concentrated on enumeration and stock-mapping techniques. As a management exercise, a working plan has been made of the Bayfordbury Woods belonging to the John Innes Charity. Studies have been made of methods of improving very abnormal age-class distributions in forests.

FOREST ECONOMICS. Apart from general surveys of economic problems and the statistics needed to deal with them, the Forest Economist has started a specific study of the place of hardwoods in the forest economy of Great Britain.

CENSUS OF WOODLANDS. The revision continues, 250,000 acres having been surveyed in the year.

STUDIES OF GROWTH AND YIELD. Twenty-seven new sample plots were established. Nine plots were lost through windblow. A provisional yield table for *Tsuga heterophylla* was published, and yield tables for oak, beech and *Abies grandis* have been compiled.

Design and Analysis of Experiments

In September, 1956, a Statistician was appointed, and a separate Statistics Section was formed, to advise all Sections of the Research Branch on the design of their experiments and sample surveys, and to analyse and report on their results.

Besides the routine work of design and analysis, investigations have been carried out into the suitability of certain designs for forest experiments, particularly of incomplete randomised blocks, and fractional replication, and into the application of the analysis of covariance, and the analysis of growth curves. Matrix methods of calculation are being used increasingly for the analysis of multiple regression and the results of systematic sampling schemes, and the possibility of using electronic computing is being explored for some of the longer analyses.

The Section has co-operated with the Working Party of Section 25 of the International Union of Forest Research Organisations on the standardisation of measurements and tests of instruments. A bulletin describing the application of statistical methods of design and analysis to forest problems has been drafted.

Machinery Research

Agricultural machines in large-scale production continue to provide the basis of many machines being introduced for forest operations. New machines designed specifically for forestry are coming forward in increasing numbers, and progress is being made on light power saws, bark peeling and extraction equipment. Mechanisation of nursery operations is increasing rapidly. Several machines for digging and clearing drains are now available, but in young plantations this problem remains unsolved. A close liaison is maintained with the Dominions and Colonies and also with the Food and Agriculture Organisation for the interchange of information.

Utilisation Development

During the year an enquiry into the use of home-grown timber in packaging and materials handling was completed. It was found that about 13 per cent of all the timber so used was home grown. There were few complaints regarding the inherent quality of home-grown timber; more commonly complaints referred to inaccurate sawing and inadequate seasoning.

Work has continued on the tannin content of home-grown coniferous bark, including variations due to the season and method of harvesting. Several private firms have shown an active interest in this work.

Studies continued on the rate of drying of Sitka spruce thinnings left lying on the forest floor, and the effects of this treatment on the quality of the timber.

An investigation into the qualities and quantities of round timber required by wood wool manufacturers was completed. The enquiry showed that home-grown timber is suitable for this market if it is properly selected and prepared.

Work has continued on the possible use of home-grown timber in traditional and non-traditional house building.

Arrangements were made to set up an experiment at nine different sites in Scotland to study the effect of preservative treatment on the life of fencing posts on different soils and under different climatic conditions.

PART II

This part of the Report consists of accounts of the progress made by workers attached to universities and other institutions. The subjects covered are usually of a more fundamental nature and much of the work is assisted by grants from the Forestry Commission.

Researches on Mycorrhiza

Dr. Levisohn, working at Bedford College, University of London, reports that differential effects on the development of birch in two different soils were attributable to *Boletus bovinus*, a well-known mycorrhiza-former. It was also observed that, in a given soil environment, different mycorrhizal mycelia can have an unequal influence on the growth of birch and Norway spruce seedlings. The physiological specialisation of mycorrhizal fungi in relationship to tree growth is under investigation.

It was demonstrated in mixed cultures on a synthetic medium that *Alternaria tenuis* inhibits the growth of a number of mycorrhiza-formers, while the growth of certain pseudomycorrhiza-formers tested are not inhibited. It is of interest that, in the nursery soils in which the presence of *A. tenuis* is very prominent, the mycorrhizal mycelia affected in pure cultures generally fail to grow, and the pseudomycorrhiza-formers not affected grow well. The fungistatic properties and effects of *A. tenuis* under natural soil conditions are being tested.

Studies on root-branching of pine seedlings have continued. The results of the experiments, carried out in water-cultures, indicate that synthetic growth-substances and exudates of mycorrhizal mycelia induce different morphological structures of branched roots.

More data on the effects of a mulch cover on tree growth and change in root infection, have been supplied by field experiments. Additional pot-culture experiments have shown that, at least under certain experimental conditions, mycorrhizal mycelia do not play a primary role in the mulching effect on the trees.

Soil Mycology

At the University College of North Wales, Bangor, Dr. Joan Bywater started work in January, 1957, on the subject of mycostasis in soils, with the aim of elucidating further the phenomenon of the inhibition of germination of fungal spores and of the growth of hyphae in soils, to which attention was drawn by the work at Bangor of Dr. W. H. Hinson, before he joined the Research Branch of the Forestry Commission.

A start has been made with assaying and comparing soils in respect of their inhibiting power, and three levels of mycostasis in soils can now be distinguished. For the first time, some forest humus samples collected in February failed completely to inhibit spore germination. The extent of seasonal variation in this factor is now being investigated.

Studies in Litter Decomposition

Dr. Raudnitz, working under the direction of Dr. W. R. C. Handley at the Imperial Forestry Institute, Oxford, continued his extraction and analysis of substances in rhododendron leaves with a view to finding the substances which render leaves resistant to decomposition by micro-organisms. None of the substances isolated so far have been found to have this property. The search continues.

Effects of Tree Growth on the Soil

Dr. Wright at the Macaulay Institute for Soil Research reports that further sampling at Culbin Forest has shown a significant though small response in height growth to phosphate manuring of Corsican pine, for the first time since the plots were laid down in 1954. Foliar analysis of Corsican pine treated with N, K, and Mg fertilisers in 1956 showed considerable uptake of these elements by the end of the first growing season.

A study, in collaboration with Mr. Will, N.Z. Forest Service, of the nutrients immobilized in growing crops of Corsican and Scots pine of different ages, and their distribution in the tree, has been accepted for publication in *Forestry*. Thirty to fifty per cent of the total nutrients in a tree are shown to lie in the bark and wood of the main stem, whose removal in utilisation thus represents a considerable nutrient loss from the site.

Mr. Binns has continued his work on the effects of afforestation on deep peat at the Lon Mor, Inchnacardoch Forest. A vigorous stand of lodgepole pine manured with phosphate, has been found to deplete the nutrient reserves of the peat considerably, particularly supplies of inorganic phosphorus and potassium, and it is possible that the yellow colour observed in larger trees of several species growing on the peat may be due to potassium deficiency. A manuring trial has been laid down in lodgepole pine and Sitka spruce to test this, and the possibility of using granite dust as a slow-acting potash fertiliser is being studied.

The investigation of the effects of thinning on the surface soil of the Norway spruce plots at Bowmont Forest has been completed, and accepted for publication in *Forestry*.

Arrangements have been made for the annual collection of samples from the long-term fertility maintenance demonstrations at Newton, Inchnacardoch, and Teindland nurseries, to study the effects of the cropping systems on the structure and nutrient content of the soils. The first season's results show the value of hop waste in the retention of nutrients.

Copper Deficiency in Poplars

Miss Benzian of Rothamsted Experimental Station has given a short note on work which has established that a black discoloration of poplar leaves grown at Wareham nursery (Dorset) is due to a copper deficiency and can be remedied by addition of very small amounts of copper compounds to the soil or as a foliar spray. Growth is at the same time considerably increased.

Fomes annosus

Dr. Rishbeth of the Botany School, Cambridge University, reports results of further large scale tests of creosoting of stumps as preventing surface infection of pine stumps by *Fomes annosus*. The treatment proved reasonably effective. Some reasons for partial failure are discussed. Treatment of stumps with certain chemicals to kill the surface tissues encourages the rapid growth of a variety of fungi, and hence the suppression of some basidiomycetes such as *Fomes annosus*.

Ecology of Fungi Colonizing Coniferous Stumps

D. S. Meredith, working at the Botany School, Cambridge University, describes the seasonal variation in the frequency of stump infection by basidiospores of *Fomes annosus* and *Peniophora gigantea*. Preliminary investigations of the surface microflora of pine needles show that there is a reservoir of fungal spores in the crowns of standing trees. *Fomes annosus* and several other species of Basidiomycetes have been isolated from this source.

Research on Keithia thujina

Mr. R. G. Pawsey, at the Botany Department, Nottingham University, working on this disease, describes how two over-wintering stages were found to be present in the life cycle of *Keithia thujina*.

One of these, the retention of incipient apothecia on infected leaves, was again confirmed experimentally during the winter of 1956-57, but as in the previous year, this apparently was not the source of the inoculum producing heavy infection in the nurseries in the spring.

Circumstantial evidence again indicated that a spore inoculum carried through the winter on the leaves was the major source of infection.

Spraying experiments based on the presence of the two over-wintering stages have been carried out at Tintern and Gwydyr.

Other research has been undertaken on the discharge mechanism of the apothecia, the aerial dispersal of the ascospores in nature, and the critical conditions controlling germination and infection.

Studies on Meria laricis

Mr. Biggs of the Botany Department, Southampton University, has continued his work on *Meria laricis* in culture. This has led to the reduction of eight strains previously recognised to four. Preliminary spore germination studies indicate that the spores of *Meria* will germinate under a wide range of temperatures. Indications from present artificial inoculations are that European larch is more easily attacked than either Hybrid or Japanese larches, and further experiments are planned to elucidate the pathogenicity of the four strains. A preliminary analysis of data from Forestry Commission nurseries has been made, final analysis of these data being withheld until receipt of 1957 observations.

Larch Canker

Dr. J. G. Manners of the Department of Botany, Southampton University has continued his work on the relationship between larch canker and *Trichoscyphella willkommii*. Anatomical investigations on various types of canker have been completed and are awaiting publication. They indicate that damage by *Trichoscyphella willkommii* occurs primarily when the cambium is dormant, and that there is a correlation between susceptibility to frost and to the fungus. Experiments on the effect of the presence of the fungus on frost-induced cracks and cankers are in progress. Preliminary results from other experiments indicate that repeated frosts probably promote the persistence of cankers caused by inoculation with *T. willkommii*. A study of the taxonomy of the Trichoscyphelloideae is nearly complete, and it has been confirmed that certain American and continental species are closely related to *T. willkommii*.

Physiology of Flowering in Trees

K. A. Longman, working under Dr. P. F. Wareing in the Department of Botany, Manchester University, has commenced a study of the physiology of flowering in forest trees, with particular reference to the possibility of hastening the onset of flowering, as an aid to forest-tree breeding.

The effect of day-length conditions on flowering is being investigated in both seedling and grafted material. Evidence has been obtained that the position of the shoot in relation to gravity is important for flower-bud formation in larch, and suggests certain techniques for promoting flowering. The effect of fertilisers and various cultural treatments on flowering in Scots pine is being studied.

Ecology of Ash

P. Wardle, working at the Botany School, Cambridge University, has made a study of the ecology of ash, and reports in particular on the factors affecting survival of seed and seedlings, as well as on factors limiting the growth of the tree after it has become established.

Morphological Variations in Conifers

Dr. E. V. Laing of the Forestry Department, Aberdeen University, has continued work on the species *Pseudotsuga taxifolia*. In our woodlands and policies there are found to be several very distinct types and a series can be got ranging from the true Green Douglas fir to the Douglas firs of Japan and China. What are called *P. vancouveriensis* and *P. glauca* of the American trees constitute the bridging species. Sufficient morphological characters have been obtained to construct a key which will be further tested out.

The abundance of cones on members of the genus *Picea* has enabled keys to be constructed to make identification more easy.

Soil Faunal Investigations

Dr. P. W. Murphy continued his investigations into the fauna, mainly mites and Collembola, inhabiting forest soils and litter. There appears to be some sequential pattern in the decomposition of litter with which a succession of fauna and flora is associated, and this is being studied. Certain mites and Collembola have been found to feed on the cysts and adults of nematode worms.

Soil Collembola in the Forest

At the University College of North Wales, Bangor, Mr. T. B. Poole completed a study on the soil collembola in a 25-year-old Douglas fir plantation near Bangor, Caernarvonshire. The soil collembola population in the plantation was estimated at a minimum of 47,000 per square metre, 85 per cent being in the organic layer of litter and raw humus, approximately 1 inch in depth. The populations exist in distinct aggregations, and were found to vary with a number of environmental factors, such as the moisture content and depth of the organic layer, the distance from trees, the compactness of the soil, and the time of year. The maximum population was in August, which is a time when other workers have shown them to be a minimum. Possibly this was related to the exceptionally wet summer in 1956. Examination of the solid food in the collembola gut showed that the larger forms feed on soil fungi and occasionally leaf litter, whereas the smaller forms feed directly on the humus. The soil collembola undoubtedly play an important role in litter breakdown, and possibly also act as vectors for fungal spores.

Effects of the Physical Environment on the Development of Bupalus piniarius

Dr. N. W. Hussey has reported on the results of experiments carried out when he was in the Department of Agricultural and Forest Zoology, Edinburgh University, on the effects of varying the temperature and the humidity on the developmental stages of *Bupalus piniarius* and the effects of these variables on frass deposition in the field. The main conclusions arrived at are:

1. Females live longer than males but both sexes can survive several weeks at low temperatures and retain fertility.
2. The minimum temperature for successful oviposition is 52°F. but optimum conditions are within a temperature range 64-73°F. and humidities of 79-95 per cent.
3. Lowest lethal effects on hatching of the eggs occur at temperatures between 62-73°F. and humidities of 53-93 per cent.
4. The optimum temperature tends to decrease with each successive instar. Exposure of the early instars to temperatures far removed from the optimum considerably increases the duration of development of the later instars, however favourable the environmental conditions.
5. *Bupalus* larvae feed several times every 24 hours. Heavy frass production indicates a large meal about two hours earlier.
6. The larval feeding rate is increased at higher temperatures. The early instars feed more rapidly in damp conditions but the 4th and 5th instars seem to show little humidity preference.
7. Field observations suggest that there are two peaks of feeding activity. The principal is nocturnal between 2100-0200 hours, but there is a smaller diurnal peak between 0800-1300 hours. The deleterious effect of cold weather and rain during the nocturnal feeding period is very marked. The most suitable feeding conditions seem to be mild, damp nights on which dew forms at temperatures above 50°F.
8. Pupal weight is greater in larvae reared at lower temperatures.
9. It is probable that the preference of *Bupalus* for dry areas is apparent, rather than real, for it is adapted to a wide climatic range. The general resistance of the larvae to disease in dryer areas may be a limiting factor restricting outbreak areas.

Shelterbelt Research

Mr. J. Neil Parker, of the Forestry Department, Edinburgh University, reports that the second phase of work on the shelterbelt project is progressing. The information assembled and techniques of climatic study developed during the first three-year period are being applied in the investigation of shelterbelt design, establishment and treatment.

The anemometer remains the principle instrument employed in climatic studies, but some attention has been given to the possibility of using evaporimeters.

A variety of fabrics have been tested in an attempt to discover whether unhemmed flags can be used to measure exposure.

Work on the establishment of new belts and the treatment of existing ones has continued, and two management plans for shelter systems on private estates have been prepared. In connection with this part of the programme nursery stocks are being increased.

The preliminary stage of a general survey of existing shelterbelts in relation to agricultural land in Scotland has been entered.

Grey Squirrels

Mrs. M. R. Vizoso of the Infestation Control Division, Ministry of Agriculture, has been working with the Forestry Commission on problems connected with the control of grey squirrels. She gives results of annual surveys of damage done, and on the distribution of grey squirrels throughout the country. No marked increase in the range of distribution has occurred during the last year. There appears to be an inverse relationship between the occupation of forests by grey and by red squirrels. There has been an increase in populations of grey squirrels resulting from greater breeding activity. The results of trials with a number of different squirrel traps are reported.

PART III

In this section, the results of certain investigations carried out by the Forestry Commission Research Branch are reported in the form of short articles. The main points of interest are summarised below.

Yield Table Construction Methods

F. C. Hummel and J. M. Christie give a brief account of the methods used in constructing the recently published revised yield tables for conifers in Great Britain. The main change from former methods was based on the discovery that, for British conditions and ranges of thinning, the relationships of top height on the one hand, and various crop characters such as total volume, total basal area, main crop volume, main crop basal area, number of stems per acre, standing crop form factor, and mean girth on the other, were independent of age or quality class. It was therefore possible to construct a "master table" on the basis of top height, from which the yield tables for different quality classes could be derived.

Seven Years' Experience of the Tetrazolium Viability Test for Conifer Seeds

G. D. Holmes and G. Buszewicz report the results of seven years of routine testing of seed germinative capacity of eleven conifer species, using both the standard Copenhagen Tank Germinator and the biochemical staining agent tetrazolium bromide ("Grodex"). The development of tetrazolium testing, and the methods of carrying out the tests, are described; and correlation and regression coefficients worked out between the results of the two methods. Using the two staining classes of "A"=fully stained embryos and "B"=embryos with less than one-sixth of the total surface unstained, it was found that for most species "A+B" values gave the most reliable estimate of germination. Exceptions were the Silver firs where "A" values (fully stained embryos) alone gave better results. No improvement in accuracy was obtained by including data of endosperm staining. Western hemlock, lodgepole pine and Corsican pine gave rather less satisfactory results than the other species tested.

Moisture Content and Specific Gravity of Spruce and Pine Bark

Messrs. J. N. R. Jeffers and R. S. Howell present a statistical study of the use of a fractionally replicated factorial design in a pilot survey of moisture content and specific gravity of spruce and pine bark, in connection with a tan-bark survey. By use of this design it has been possible, on a far smaller number of samples than would have been necessary with a completely random sampling design, to determine overall figures for the moisture content and specific gravity of bark, and the dependence of these on position of the sample in the tree, and the age of the trees. Estimates of variance are given which will enable future surveys to be planned and stratified, so as to give results to any predetermined degree of accuracy. It was also found that moisture content did not vary with species (between pines and spruces), season of collection, dominance of the trees or quality class of the stand. These factors can therefore be ignored in future sampling surveys. This use of the device of the fractional replication of a 2^s factorial design has, therefore, very greatly increased the information obtainable from a pilot survey of very modest size.

Chloropicrin compared with Formalin as a Partial Soil Sterilizing Agent in Forest Nurseries

The results of a series of experiments started in 1953 in a number of nurseries in Scotland and Northern England are reported on by Mr. R. Faulkner. It was found that chloropicrin applied by injection into nursery seedbeds at a depth of four inches, and at rates from 0.62 to 0.83 gallons per 100 square yards (thirty to forty gallons per acre) is usually a slightly more effective sterilizing agent than formalin, as gauged by the height growth and yield of usable one-year seedlings of Sitka spruce. It is essential however that the chloropicrin is applied at least 30 days before sowing and preferably in the previous autumn. Using machine application, the cost of applying 30 gallons per acre worked out at about ten pence per square yard, in 1957, or approximately 1/7d. per thousand usable seedlings.

PART I

Reports of Work carried out by Forestry Commission Research Staff

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES and G. BUSZEWICZ

232.31*

As in all recent years, the work of the Alice Holt Seed Laboratory was divided between routine testing of seed quality, and research work on problems of seed collection, extraction, storage and testing. Routine testing of the purity and germination quality of the Commission's seed continued to have priority, and research work was organised as permitted by the programme of routine testing.

The test methods employed in routine work are based on the prescriptions of the Seeds Act (1920) and Amendments, and the International Rules for Seed Testing. However, for many less common or dormant tree seeds these prescriptions are not sufficiently precise, and frequently several methods of testing have been tried when samples of such species are received. By this means it is hoped to accumulate evidence from routine testing which will assist in improvement and standardisation of test methods for these minor species. The alternative of detailed experimental work on each species is impossible at present owing to the weight of other work.

In the year under review 666 samples were received on which the following tests were completed:

Purity analyses	430
Germination tests	972
Tetrazolium tests	121
Moisture content tests	161

Reports were also issued on 88 cone samples received from Conservancy collection areas during the year.

In addition to the above, more than 100 germination and tetrazolium tests were completed in connection with the experimental work described below.

An innovation during the year was the introduction of a statement of the number of viable or germinable seeds per lb. on all test certificates issued. This figure takes account of variations in purity, seed size and germination quality for each lot, and is considered a useful expression of seed quality for sowing. Revised formulae for sowing density calculations on this basis have been recommended. The issue of interim reports on urgent samples is now an established practice, the statements being based on the germination percentage after a few

*This and similar numbers refer to the Oxford System of Decimal Classification for Forestry.

days on the germinator, or on the results of a tetrazolium viability test. Such reports are always followed by a final test report which constitutes the only legal declaration of seed quality. At the end of 1956, two new refrigerators, each of 3 cu. ft. capacity, were installed in the laboratory. These are operated at temperatures of —10°C. and +8°C. respectively, and are used in conjunction with the existing +2°C. constant temperature chamber for seed storage experiments and seed pretreatment.

Seed Storage and Seed Longevity 232.315.2

The small constant temperature storeroom at Alice Holt has a yearly turnover of about 250 lb. of seed, made up of large numbers of small lots required by Research Sections for experimental work. Seed despatch to Research and other centres, including seed packeted for unit plots in nursery experiments, involved over 6,000 measured and packeted lots during the period March-April 1957. The construction of the new refrigerated seed store for the Forestry Commission's seed is now well under way as part of the new wing to the Research Station at Alice Holt.

Storage Conditions

(a) CONIFER SPECIES. The existing long term storage trial with seed of common conifers was continued into its seventh year. Results confirm previous indications that viability can be maintained at a high level, providing the seed is stored at a constant low temperature and moisture level. More information is required about the inter-relationship of seed moisture content and storage temperature as affecting seed longevity, and new experiments are being laid down covering a wider range of temperature and moisture conditions.

(b) BEECH NUTS. The irregularity and infrequency of good seed years of beech leads to considerable practical difficulties in ensuring a regular supply of good plants for annual planting programmes. Storage of seed for the lean years is the obvious solution, but in fact no means of storing beech seeds for a period longer than one year are known at present. Experiments in 1950 (vide Report on Forest Research 1951 and 1952) failed to indicate methods of maintaining viability for longer than 18 months. In view of the practical importance of this project, the good seed year of 1956 was taken as an opportunity for further investigation of the storage requirements of beech, and an extensive trial of seed pre-treatment and storage methods was laid down. The conditions applied include storage temperatures of —10°C., +2°C. and +8°C., and seed moisture levels ranging from 10 to 30 per cent, the latter being near the normal moisture content of fresh seed. Beech is susceptible to excessive drying, and reduction of the moisture level below about 15 per cent by normal drying methods can seriously affect germination quality. Consequently, drying to reduce respiratory activity and prolong longevity cannot be utilised to the same degree as for many conifer seeds. Even at the 15 per cent moisture level, respiration proceeds at an appreciable rate, which makes for difficulties in maintaining a constant moisture level by the simple expedient of placing the seed in a sealed container. The present tests include this treatment, but they also include aerated storage in which the seed moisture levels are maintained in a slow air stream of controlled relative humidity. The possibility of suspending seed metabolism without loss of viability by rapid deep freeze techniques is also under investigation.

Checks of seed moisture content and germination power are carried out at three-month intervals, and will be continued as long as any useful proportion of germinable seeds remains in any treatment.

Seed Testing 232.318

(a) BIOCHEMICAL TESTS. Work was continued in summarising the results of six years' investigations of the tetrazolium viability test and its relationship with normal germination methods and plant per cent in the field. It is hoped to complete this work for publication in 1958.

On the basis of this work, the tetrazolium test is employed as a routine test on urgent samples for the issue of interim reports. In the last few years, many hundreds of such tests were completed, and an effort has been made to analyse the results in comparison with normal germination test methods. A report on these analyses is given on p. 142 of this report.

(b) SEED MOISTURE CONTENT. Work was continued in standardisation of the drying time at 105°C. with the oven method of moisture test. Results of previous tests are now being analysed to determine the shortest standard drying period. Time did not permit calibration of a grain moisture hygrometer for rapid moisture estimation as intended. However, this work will proceed, together with trials of an infra-red moisture meter with the aim of developing a quick reliable technique for routine checks on stored seed.

(c) SEED-BORNE FUNGI. Records of the incidence of fungi during the course of germination tests were continued by Dr. S. Batko of the Pathology Section. The previous lists (vide *Reports on Forest Research* 1952-56) have been enlarged by records of the following fungi:

Monochaetia spp. — on home collected *Araucaria araucana* seed.
Melanospora zamiae — on *Abies* spp.
Trichoderma viride — common on all species.
Fomes annosus (*Heterobasidion annosum*) on *Abies nobilis*.

Tests of pathogenicity of selected fungi will shortly be started on completion of trials of methods of surface sterilization of seeds prior to specific inoculation of treated seeds.

NURSERY INVESTIGATIONS

by R. FAULKNER and J. R. ALDHOUS

232.322.2

Partial Sterilisation

Current work has concentrated on, firstly, trying to find a method of using formalin undiluted, so as to avoid the expense and trouble of handling large quantities of water in the nursery, and, secondly, in trying to discover alternative chemicals that may be cheaper and more effective than formalin.

Time, Rate and Method of Applying Formalin

The experiment, described in the 1956 *Report on Forest Research*, comparing applications of formalin at 5 gallons or 10 gallons per 100 square yards of seed-bed, and made either in late autumn (November) or in spring (3-4 weeks before sowing), and either as an undiluted surface spray or as a diluted drench, was repeated in five northern nurseries. One extra method of application was tested, namely, the placement of undiluted formalin in drills 1½ inches deep, 1 inch wide and 3½ inches apart. This treatment had shown promise in some southern nurseries in 1955. Sitka spruce was sown as the indicator species.

None of the treatments produced any important differences in the total numbers of seedlings. Weeding times were not affected by either the concentration of formalin or the method of application. Spring applications generally gave better control than autumn applications.

The higher rate of application of formalin produced a highly significant height increase when compared with the lower rate, although at Fleet Nursery the reverse was true. At four of the five nurseries, undiluted applications of formalin applied to the soil surface were followed by smaller seedlings than the other treatments. At four of the nurseries there were no significant height differences between drilled undiluted formalin or drench treatments. Autumn applications of formalin produced taller seedlings than spring applications. These experiments, together with the experiments of 1955, strongly suggest that 10 gallons of formalin per 100 square yards is to be preferred to the 5 gallon rate. Autumn is generally a more satisfactory time to apply the formalin than spring, and undiluted drilled formalin, or diluted formalin applied as a drench, are almost equally effective. Applications of undiluted formalin to the surface of the soil are not very effective.

"User" trials of Chloropicrin and Formalin by injection

The Auchencruive Injector, which was originally designed by the West of Scotland Agricultural College for injection of "D-D" for potato eelworm control, has been successfully adapted for the large scale injection of formalin and chloropicrin in forest nurseries. In a series of experiments in five nurseries in England and Wales, the effects of injecting formalin at a rate of 4.2 gallons per 100 sq. yards (200 gallons per acre) at 2 inches depth in drills five inches apart, were compared with injecting chloropicrin at 0.7 gallons per 100 square yards (34 gallons per acre) in drills at 6 inches depth ten inches apart. Two injection units were used to provide the eight formalin drills and one unit for the four chloropicrin drills. (Previous tests had shown that the maximum delivery rate of the injector with eight tines spaced at five inches, and travelling at two miles per hour, was 200 gallons per acre). Higher rates could almost certainly have been obtained by enlarging jet and tap apertures.

Responses to sterilization were small, but appeared as great in plots where sterilants had been injected by machine as they were on plots treated by hand. Similar large scale "user" trials of chloropicrin injected by a modified Auchencruive "D-D" injector were successfully repeated at four Scottish nurseries. Chloropicrin was injected at the rate of 0.6 gallons per 100 square yards (30 gallons per acre) and at a depth of 4 inches. These trials were not assessed but the benefits of sterilization were visibly obvious.

Nursery Manuring

Rate of Application of Nitrogen, Potash and Phosphate fertilizers 232.322.41

The experiment referred to in the 1955 Annual Report was repeated at six nurseries using Japanese larch, Douglas fir and Sitka spruce as indicator species. This experiment is a factorial combining phosphorus fertilizers at normal, one-and-a-half times and twice the normal rates; potassium fertilisers at normal, double and triple rates, and nitrogen at normal and twice the normal rates, in order to determine their single or combined effects on seedlings growth.

JAPANESE LARCH. There were two experiments at different nurseries with Japanese larch. Both of these showed that double the normal rate of nitrogen (50 oz. N per 100 square yards) produces a considerable and significant height increase.

Data for phosphorus and potassium fertilizers were less conclusive. At Fleet nursery none of the treatment differences were significant. At Inchnacardoch however the phosphate application at each of the increased rates (60 or 80 oz. P_2O_5 per 100 square yards) produced significant height increases, whereas potash at the increased rates (60 or 90 oz. per 100 square yards) caused a significant reduction in heights.

None of the treatments had a significant effect on the numbers of seedlings.

DOUGLAS FIR. The experiment with Douglas fir at both Benmore and Wykeham showed that the double rate of nitrogen produces a highly significant increase in seedling heights. There were no significant height differences between the three concentrations of phosphate, but the highest rate of potash resulted in reduced seedling heights at Wykeham. At Benmore there were no significant differences between treatments for the three rates of potash.

None of the treatments had any effect on seedling numbers.

SITKA SPRUCE. Six experiments were carried out using Sitka spruce. The higher rate of nitrogen had a significant effect only at Benmore, where it produced smaller seedlings than the lower rate. Increased phosphate had no effects on seedling heights except at Wykeham and Bush where both of the higher rates produced taller seedlings and at Inchnacardoch where the highest rate resulted in significantly shorter ones. The higher rates of potash had no significant effect on seedling height at any nursery.

Seedling numbers were not affected to any great extent by any of the treatments.

The general conclusion to be drawn from these results is that the present standard of phosphate and potash manuring in Scotland is usually quite adequate for Japanese larch and Douglas fir as well as for Sitka spruce, but that some increase in the rate of nitrogen would benefit Japanese larch and Douglas fir. This is confirmed for Japanese larch in the experiment discussed below.

Time and Rate of Applying Nitrochalk to Conifer Seedbeds

The 1955 experiment comparing three rates of nitrogen (12.5, 25, and 37.5 oz. N per 100 square yards) applied in June, July or August as "Nitrochalk", was repeated for a second year in five northern nurseries, using Scots pine, Douglas fir and Japanese larch as indicator species. The details and reasons for the experiment have been previously summarized in the Research Report for 1955, the main object being to see whether heavy and late applications of nitrogen fertilisers increase the susceptibility of plants of these species to damage by autumn frosts by delaying "hardening off". Though summer rainfall was above average, summer temperatures were lower than average in most nurseries in 1956, and for this reason the responses to nitrogen were below normal.

JAPANESE LARCH. This species was used at three nurseries. Results at Inchnacardoch were unreliable, due to very poor germination of seed. At the remaining two nurseries the results were somewhat variable. At Bush Nursery, July applications produced much taller seedlings than either the June or August treatments, whereas at Benmore it was the August applications which were outstandingly the best. The two highest rates of application, which correspond to double or triple the normal rates applied in Conservancy nurseries, produced significantly taller seedlings than the lower rate.

DOUGLAS FIR. Neither the time nor rate of application had any significant effect on seedling heights at Benmore, although the data suggested a progressive increase in height with increased rate. At Fleet, August applications produced much taller seedlings than applications in June or July, and the two higher rates of "Nitrochalk" both produced significant height increases when compared with the lowest rate.

SCOTS PINE. The experiment with Scots pine at Inchnacardoch failed, but at Wykeham and Tulliallan it was shown that July and August applications are more effective than June applications. The rate of application did not affect seedling growth.

Seedling numbers were not affected by either the date or rate of application for any species at any of the nurseries.

These experiments, and similar experiments in previous years, indicate that double or triple the present Conservancy rates for nitrogen would benefit seedbeds of Japanese larch and Douglas fir where the object is to produce large usable first year seedlings. Applications are generally most effective when applied in July or August in two doses. For Scots pine the current rates of application seem quite suitable if applied in July or August, although when the 1955 results are taken into consideration some increases in the rates of application may seem to be quite justifiable. There were no cases of increased frost injury to seedlings receiving the higher or later applications of nitrogen.

Similar experiments, in which nitrogen fertilisers were applied to seed beds of Douglas fir and Japanese larch, were carried out in four nurseries in England. Nitrogen was applied as "Nitrochalk" in the heathland nurseries at Wareham and Bramshill at 2, 4, 6 and 9 lb. per 100 square yards, and as ammonium sulphate in the old agricultural soil nurseries at Kennington and Ampthill at rates of $1\frac{1}{3}$, $2\frac{2}{3}$, 4 and 6 lb. of ammonium sulphate per 100 square yards. (Applications of both materials were equivalent to approx. 1.3, 2.7, 4 and 6 grams nitrogen per square yard). The standard dressing for most conifer seed beds is 6 lb. of Nitrochalk or 4 lb. of ammonium sulphate per square yard. Dressings were applied in June, July and August, plots receiving one or two dressings. (Dressings in June and July are standard practice.)

Both species responded to the heavier rates of nitrogen application by increased growth and improved colour. Japanese larch showed a greater range of colour and growth responses than did Douglas fir.

No early autumn frost occurred at any nursery. Frosts occurring at the end of October did no damage to seedlings in any treatment.

It was observed that the formation of terminal buds was delayed on plants receiving the heavier or later nitrogen applications, compared with control plants. Table 1 below gives results of an assessment of the percentage of plants which had formed their terminal buds in mid-October, 1956.

Plants from a similar experiment in 1955 were lined out at Bramshill Nursery. No differences in survival in the lines nor in susceptibility to winter frost were observed.

Table 1

Formation of Terminal Buds

Treatment	Percentage of Plants with terminal buds formed in Mid-October			
	Japanese larch		Douglas fir	
	Kennington	Ampthill	Kennington	Ampthill
Control—No Nitrogen	99%	93%	36%	61%
Nitrochalk at 9 lb. per 100 sq. yds. in July and August	81%	57%	7%	20%

Use of Ammonia as a Nitrogen Manure of Sitka spruce Seedlings 232.322.411

In many of the experiments carried out by the Nursery Nutrition Sub-Committee, it has been shown that Sitka spruce seedlings respond to "ammonia" nitrogen more than to "nitrate" nitrogen. For this reason six experiments were carried out in the north to determine whether .880 ammonia solution would produce any greater response to seedling heights as compared with "Nitro-chalk". The experiment compared .880 ammonia with "Nitrochalk" applied either on the date of sowing, or in mid-July (the ammonia was injected by hand), and also compared "Nitrochalk" applied at rates equivalent to 25 oz. N per 100 square yards with ammonia at rates equivalent to 25, 50 and 75 oz. N per 100 square yards.

The results of these experiments showed that at five out of the six nurseries there were no significant differences in either heights or yields of seedlings for any of the treatments. At Newton nursery, however, "Nitrochalk" produced much taller seedlings than the two lower rates of ammonia.

From these experiments therefore it is clear that for Sitka spruce .880 ammonia solution has no advantage to offer over the standard method and rate of application of "Nitrochalk".

A large scale "user" trial of equipment for the injection of gaseous ammonia was made at Widehaugh nursery, Northumberland, in collaboration with the staff of the Agriculture Department of Newcastle University. Seedling growth over the whole of the trial area was poor and no conclusive results were obtained.

Use of Urea as a Nitrogen Manure for Sitka spruce seedlings 232.322.43

Experiments in which "Nitrochalk" was compared with commercial urea, at standard and double the standard rates of nitrogen application, and applied either before sowing or as two top dressings in July and August, were sown with Sitka spruce in seven nurseries. The experiments were designed to show whether urea is a more suitable nitrogenous fertilizer than "Nitrochalk" for conifer seedlings, since it has been shown in earlier work that slower acting organic fertilizers often give improved growth when compared rate-for-rate with inorganic forms of nitrogen.

The results were disappointing and may in some way be accounted for by the cold, wet, sunless summer. There were no significant height differences between either the two rates of application (25 or 50 oz. N per 100 square yards) or between the "Nitrochalk" and the urea, but top dressings of the nitrogenous fertilizers invariably produced slight but highly significant height increases when compared with pre-sowing applications. Urea-treated seedlings were reported as being deeper green in colour at the end of the growing season.

From these experiments it is clear that urea has negligible, if any, advantages to offer over "Nitrochalk" as a nitrogenous manure. The results may have been affected by the unfavourable climate during the growing season, and for this reason the experiments are being repeated at four nurseries in 1957.

Sterilization, Hopwaste and Lime Applications 232.322.2

The two experiments comparing the effects of partial soil sterilization, lime and hopwaste in two sections of Newton nursery where a decline in fertility has been observed, were re-sown with Scots pine and Japanese larch without further special treatment. The experiments were started in 1955 and consisted of factorial combinations of a formalin drench treatment at standard rates, hopwaste application at approximately 8 cwt. per 100 square yards and ground mineral limestone at approximately 17½ lb. per 100 square yards.

The residual effect of the sterilization and hopwaste treatments produced pronounced growth effects on both species and at each site, but the small lime applications produced neither beneficial nor adverse effects. These experiments will be re-sterilized and treated with lime again before sowing in 1957.

Long-term Fertility Demonstrations 232.322.1

The long-term fertility demonstration at Teindland woodland nursery continued into its seventh year. Sitka spruce and lodgepole pine are used as indicators for the main treatments which are: no manures, artificial fertilizers only, hopwaste only and combination of the two.

In the Sitka spruce section there were highly significant differences in height between the three manuring treatments and the unmanured control, and between the hopwaste and the artificial fertilizer treatments. Artificial fertilizers in combination with hopwaste produced significantly smaller seedlings than hopwaste only, and also significantly reduced the yield of seedlings when compared with the control and pure fertilizer treatments.

None of the treatments had any significant effect on the height or yield of seedlings in the lodgepole pine section.

Table 2

Teindland Woodland Nursery Fertility Demonstration
End of Seventh Year. Heights and production Figures for Sitka spruce and lodgepole pine one year seedlings

Treatment	Sitka spruce			Lodgepole pine		
	Mean Hts. in.	Nos. per sq. ft.	% over 1½ in. tall	Mean Hts. in.	Nos. per sq. ft.	% over 1½ in. tall
No manures or hopwaste	0.62	108	0.6	0.82	95	2
Artificial fertilizers only	0.90	101	7	0.91	91	1
Hopwaste only	1.20	95	22	0.98	83	9
Artificial fertilizers and hopwaste	1.07	88	14	0.96	78	5
Standard Error ±	0.04	3.7	—	0.05	6	—
Critical 5%	0.13	13	—	Not	Not	—
Differences 1%	0.20	—	—	sigt.	sigt.	—

The Newton long-term demonstration started on the second rotation. Some of the prescriptions for organic and artificial fertilizers were slightly modified in order to accord with modern manuring practice. At Fleet the whole demonstration was under transplants. Soil samples from all fertility demonstrations in Scotland were sent to the Macaulay Institute for an analysis of the size of the soil aggregates. This is the beginning of a long-term project in which more information on the physical properties of the soil under different treatments will be obtained.

The demonstration of fertility maintenance following regimes prescribed by Dr. Rayner was continued at Wareham Nursery, Dorset. Growth both of transplants and of seedlings was generally good. Sitka and Norway spruce seedlings sown for the second successive year on beds dressed with hop compost at the rate of 230 lb. per 100 square yards (5 tons per acre) showed reddish discolorations characteristic of potassium deficiency, whereas seedlings of the same species on seedbeds given either hops compost at 460 lb. per 100 sq. yards (10 tons per acre) preceded by a winter mulch of bracken, or bracken/hops compost at 230 or 460 lb. per 100 sq. yards, were green in colour. This agrees with the observation made in 1954 that the bracken mulch appeared to leave sufficient potassium in the soil to counter-balance the known shortage of potassium in hop compost.

The demonstration of fertility maintenance at Bramshill Nursery, Hampshire, was continued and seedbeds were sown with Sitka spruce for the sixth consecutive year. Here results closely followed those of previous seasons. Plants on control plots were very small, though of good colour. There was little to separate plants on manured plots whether the plots were treated with bracken/hops compost, NPK fertilizer or both compost and fertilizer together. However, seedlings on plots given compost alone were slightly bigger than those on NPK plots.

Amelioration of Heavy Soils 232.322.5

At Tair Onen Nursery, Glamorgan, an experiment, in which in 1955 a two-inch layer of fine-grained charcoal had been incorporated into the top 4 to 5 inches of the soil, was sown with Sitka spruce, Japanese larch, Corsican pine and oak. While the differences in numbers of seedlings per square yard and in the heights of spruce and pine were small, Japanese larch seedlings were considerably and oak appreciably taller on plots treated with charcoal than those on control plots. This is a reversal of the situation at the end of the first year of this experiment when all crops on charcoal plots were inferior to those on the controls.

A similar experiment at Ddwylig Nursery, St. Asaph, Flint, was a failure due to bad germination both on control and treated plots.

At Ddwylig Nursery, St. Asaph, Flint, a study was made of the effect of green crops on soil workability. Lining-out into a rye grass and clover crop, which had been sown in August, was slower than lining-out on ground which had been fallowed and ridged, or which had carried in late summer a crop of lupins ploughed in after flowering. The surface soil carrying grass was quite wet and heavy at lining-out, whereas the soil surface on ridged ground at the same time was moderately dry and friable.

The autumn was particularly favourable to grass growth and it is probable that had a slower growing strain of grass been sown, or had the grass been sown two or three weeks later, lining out into the grass green crop would have been more successful.

Date of Sowing 232.323.3

It has recently become a common practice in southern England to sow oak and beech in the autumn with an extra thick covering of soil in preference to spring sowing with consequent storage difficulty. While results have been generally satisfactory in practice, close comparisons have not, till now, been made.

An experiment comparing spring and autumn sowing of oak, with and without extra soil cover during the winter, was carried out at Kennington Nursery, Oxford. An extra 4- to 6-inch layer of soil was applied to certain autumn sown plots in order to determine whether such an additional layer gave protection against vermin during the winter months. This extra soil cover is normally removed in early spring. No differences in yield or growth of seedlings sown in autumn or spring were found. No damage by mice or birds occurred on the experiment during the winter, so that no information was obtained about the protection afforded by the extra soil. The extra soil cover caused no reduction in crop yields as long as it was removed in the spring; however, extra soil put on in the autumn and left on for the whole of the season reduced yields very significantly.

An experiment on the date of sowing of Sitka spruce, Corsican pine, Japanese larch and *Tsuga heterophylla* was carried out at Kennington Nursery, Oxford. This experiment, which is repeated annually, serves to relate the growth of seedlings in other experiments sown on differing dates. Seed was sown at approximately fortnightly intervals from mid-March to mid-May. Germination was irregular and slow, due to the lack of rain in the three months March, April and May, during which period only 2.32 inches of rain fell. Plots sown in March and April carried the greatest number of usable seedlings. May-sown plots were better stocked and more uniform, but seedlings were mostly too small to be usable.

Seedbed Coverings 232.323.5

Experiments comparing the behaviour of Sitka spruce and *Abies nobilis* seed, covered with St. Austell grit to depths of 1/8th, 3/16th, ¼ and ½ inch, were carried out at Wareham Nursery, Dorset, Kennington Nursery, Oxford and Ampthill Nursery, Bedfordshire. The experiments were carried out to examine the suggestion from Nursery Nutrition sub-Committee's experiments that Sitka spruce responded to greater depths of covering than are currently recommended. Results from the three nurseries were similar and showed that the yield of Sitka spruce seedlings was highest when seed was covered with 1/8th—3/16th inch of grit. The germination and growth of *A. nobilis* was generally poor but was significantly or appreciably better under the thicker coverings than the thinnest, as shown in Table 3.

Table 3

Effect of Depth of Cover on Germination of Conifer Seed

Thickness of cover (inches)	Seedling numbers per square yard					
	Sitka spruce			Abies nobilis		
	Ampthill	Kennington	Wareham	Ampthill	Kennington	Wareham
⅛	428	1032	277	14	39	9
3/16	479	1172	319	25	69	15
¼	282	1023	254	26	70	22
½	42	433	225	49	71	19

Nursery Treatment of Abies

Whereas satisfactory nursery techniques have been worked out for most of our commonly planted species, the Silver firs frequently give trouble, and backward, poorly stocked beds of various species of the genus are a not unusual sight. A special study is, therefore, being made of the nursery treatment of this genus.

Stratification of Abies seed 232.315.3

At Kennington Nursery, Oxford, seed of *Abies nobilis* stratified for one, two or three months, was sown in mid-March in comparison with seed sown dry in early December and in mid-March.

The yield of seedlings was greatest from seed stratified for two or three months; seed sown dry in mid-March was slow to germinate and yielded fewest seedlings. There were no significant differences in seedling heights.

Date of Sowing of Abies grandis 232.323.3

Autumn sowing is frequently practised in America to obtain maximum yield of seedlings for certain *Abies* species. For this reason experiments were carried out at Fleet and Inchnacardoch nurseries in which the height and yield of seedlings produced from *Abies grandis* seed sown in October, November, February, March and April were compared.

There were no significant height growth differences between treatments at Inchnacardoch, but at Fleet height growth of the two late autumn sowings was significantly greater than the spring sowings. At both nurseries the autumn sown seed germinated quickly and winter losses by frost were very heavy. Highest yields were recorded for the April sown seed.

From these two experiments it is apparent that under Scottish conditions autumn sowing of *Abies grandis* is an unsuitable method. Late March or April sowing is recommended.

These results are confirmed in the south where seed of *Abies nobilis* was sown at Kennington Nursery, Oxford, in early December and at fortnightly intervals from early March to early May. The table below gives the mean height and numbers of seedlings in each treatment:

Table 4

Effect of Sowing Date on Abies nobilis Seedbeds

Date of Sowing	Seedling Numbers per square yard	Seedling Height (inches)
December 2nd	47	1.86
March 5th	313	1.33
March 24th	284	1.48
April 6th	178	1.18
April 23rd	61	0.73
May 5th	37	0.93
Standard error	—*	±0.17

*No standard error for numbers is given as it was necessary to transform the numbers logarithmically and calculate the standard error of the transformed figures.

The number of seedlings obtained from March sowings was very significantly higher than the number of seedlings from other dates of sowing; also, seedlings from March sowings were significantly taller than late April and May sowings. Seedlings from the December sowings were appreciably or significantly taller than all those raised from spring sowings, but the number of seedlings was very low.

Seedbed Covering Materials and Depth of Cover for Abies grandis 232.323.5

The 1954 and 1955 experiments comparing soil and grit cover at depths of 0.25, 0.5 and 0.75 inches over *Abies* seed was repeated in Scotland at Benmore, Bush and Fleet, using *Abies grandis*.

At all nurseries the soil cover produced slightly taller seedlings than the grit cover. This is believed to be largely an artificial effect due to the removal of appreciable amounts of top soil during weeding operations. Depth of cover had only a slight influence on seedling heights, but at two of the nurseries the 0.25 inch cover depth grew the tallest seedlings, whereas at Fleet both the 0.5 and 0.75 inch deep cover produced significantly taller seedlings than the 0.25 inch deep cover. Grit cover produced a significant increase in seedling yields at all three nurseries. None of the depth treatments affected seedling heights.

During the past three years, five experiments on seed covering have been carried out in Scotland with *A. grandis*, two with *A. lowiana* and one with *A. nobilis*. Results have varied considerably from year to year but taken overall it appears that grit covers generally increase the yield of seedlings per lb. of seed, and that the most satisfactory depth of cover is between $\frac{1}{4}$ and $\frac{1}{2}$ an inch.

Irrigation of Nursery Beds 232.325.1

At Kennington nursery, Oxford, an experiment was carried out comparing the growth of seedlings and transplants (a) with and without water applied by overhead irrigation when the estimated soil moisture deficit exceeded half an inch of rainfall, and (b) with nitrogen applied either through the irrigation system or dry to seedbeds. Nitrogen was applied through the irrigation system on one series of plots in two applications, one in mid-June and the other in mid-July, and on another series of plots in weekly applications through June and July. Equivalent amounts of nitrogen were applied on all plots. Results appear in Table 5.

It will be seen that, except for Corsican pine and red oak, the yield of seedlings of all species was increased by irrigation by between sixty and several hundred per cent. Also, seedlings were bigger, so that a larger proportion of them were usable.

The response by most species to nitrogen applied through the irrigation system was not so great as when the same amount of nitrogen was applied dry. This is shown by the mean height of seedlings, but was also apparent from the colour of some seedlings at the end of the year; Sitka spruce especially were yellow-green in colour on plots receiving nitrogen through the irrigation system, but deep green on plots given dry nitrogen. Beech transplants which received nitrogen through the irrigation system showed scorch of foliage, apparently where drops of nitrogen-rich water had remained, in spite of attempts to wash off all such water by continuing to irrigate for five minutes after all the nitrogen had been passed through the pipes. On ground given a weekly application of irrigated nitrogen, and to a lesser extent on ground given monthly application of

Table 5

Plant Numbers and Heights—With and Without Irrigation and Nitrogen Manuring: Kennington, 1956

Treatment	Number per sq. yd.				Mean Height—Inches			
	Control	Water +dry N	Water +N in irrigation monthly	Water +N in irrigation weekly	Control	Water +dry N	Water +N in irrigation monthly	Water +N in irrigation weekly
Seedlings Species								
Sitka spruce	330	1,302	1,149	1,443	1.4	4.5	2.0	3.0
Corsican pine	345	385	331	406	1.4	1.8	1.6	1.8
Lawson cypress	267	984	840	987	1.5	3.9	3.2	4.0
Japanese larch	322	591	606	861	3.2	8.1	4.3	4.9
Douglas fir	353	540	486	495	3.3	7.3	4.9	6.7
Abies grandis	21	149	157	144	0.7	1.1	0.9	1.2
Abies nobilis	19	167	145	111	0.8	1.7	1.6	1.6
Red oak	88	100	90	90	5.8	·8.1	6.6	6.8
Transplants								
Beech	—	—	—	—	5.9	6.9	6.6	6.5
Norway spruce	—	—	—	—	6.9	9.1	8.3	10.1

irrigated nitrogen, there was quite a heavy growth of algae on paths and strips between plots.

The weather in late spring of 1956 was very dry, though fairly cool, and one would expect a good response to irrigation. From April 23rd, when seed in this experiment was sown, until June 2nd, only 0.53 inches of rain fell. During this time, eight applications of water equivalent to 3.32 inches of rain were made. During the remainder of the summer a further seven applications equivalent to 2.72 inches of water were necessary.

Dr. A. J. Rutter of Imperial College, London, collaborated in this experiment and enabled us to study moisture tensions in the soil under the different treatments.

Soil moisture tensiometers were installed at 2, 6 and 18 inches below the soil surface. Throughout the experiment the tensiometers at 18 inches scarcely varied in their readings. On unirrigated plots the moisture tension at 2 inches below the soil surface rose slowly during May, and by the end of the month was sufficient to raise 30 cm. of mercury; at six inches the tension was 20 cm. of mercury. Nearly an inch of rainfall, falling over the period of a week in early June, was necessary before tensiometers at 2 and 6 inches recorded no tension. At no time subsequently did tensions rise to this level in unirrigated plots. Only at the end of September, in two or three days of warm weather, did tensions rise and these rises were most rapid on irrigated plots. By this time the crop differences due to early irrigation, i.e. increased numbers and heights of seedlings on the irrigated plots were fully developed. Greater demands would therefore be expected from a denser and larger crop. On the irrigated plots, in ten days without water, the tension rose to over 50 cm. of mercury at 2 inches, and to 20 cm. at 6 inches, while on unirrigated plots in the same time the tension reached 20 cm. at 2 inches and 10 cm. at 6 inches.

A most important indication arising from the tensiometer readings is that the irrigation regime was probably somewhat extravagant in the use of water during the germination period, and that applications of 0.25—0.3 of an inch at intervals previously used, rather than application of 0.5 inches, would be sufficient to keep the top 6 inches of soil thoroughly moist at this time.

Weed Control in Nurseries

Pre-emergence Weedkillers 232.325.24

A new material, S.1112, prepared by Shell Chemicals as a pre-emergence weedkiller, was tested at Bramshill Nursery, Hampshire; Kennington Nursery, Oxford; and Ampthill Nursery, Bedfordshire. At no nursery was the yield or height of Sitka spruce seedlings reduced; however, it took a very significantly longer time to weed plots treated with S.1112, compared with plots given a standard pre-emergence spray of vaporising oil.

At Bramshill Nursery, an experiment was carried out in which allyl alcohol, a material which is a most effective pre-sowing weedkiller when applied as a drench, was applied in this manner and also by injection in undiluted form. Application of any material as a drench is a costly and time-consuming operation, and the object of the experiment was to determine whether undiluted allyl alcohol was as effective as when diluted. Crops were undamaged by any applications; Table 6 below gives the time taken to weed different treatments.

Table 6

Effect of Allyl Alcohol Treatments on Weeding Times

Treatment	1st weeding* time mins.	Total weeding* time mins.
Allyl alcohol drench at ⅓ gallon + 100 gallons water per 100 sq. yd. (16 gallons in 5,000 galls. water per acre)	0.43	5.80
Allyl alcohol drench at ½ gallon + 100 gallons water per 100 sq. yd. (24 gallons in 5,000 galls. water per acre)	0.45	5.17
Allyl alcohol injected at ⅓ gallon per 100 square yd. (16 gallons per acre)	3.10	15.97
Allyl alcohol injected at ½ gallon per 100 square yd. (24 gallons per acre)	3.77	14.83
Comparison plot—Pre-emergence spray of vaporising oil at 1¼ gallons per 100 sq. yd. (60 gallons per acre)	1.20	11.80
Control plot, handweeding only	9.61	22.28

*Weeding unit area: 2 sq. yd.

It will be seen from this that weeding time on plots injected with *undiluted* allyl alcohol were considerably greater than on plots sprayed with vaporising oil, but on plots given an allyl alcohol *drench*, the weeding time was considerably less than on plots sprayed with vaporising oil.

At Kennington, Bramshill and Ampthill Nurseries, experiments were carried out comparing two chemicals C.D.A.A., (alpha-chloro-N, N-diallylacetamide) and C.D.E.C., (2-chloroallyl-diethyl-dithiocarbamate), both of which had shown promise as weedkillers applied before sowing in similar experiments in 1955. Materials were applied at the rate of 40, 60, 80 and 100 grams per 100 sq. yd. (4, 6, 8 and 10 lb. per acre) in water at 1¼ gallons per 100 square yd. (60 gallons per acre).

It was found that C.D.A.A. was more effective as a weedkiller than C.D.E.C., but also that it damaged seedling crops of Japanese larch and Sitka spruce more severely. The degree of damage was not consistent from one nursery to another. Control of weeds was better and crop damage more severe on plots where the chemicals were cultivated into the top two to three inches of the soil, as compared with plots where the chemicals had been left on the soil surface.

Post-emergence weedkillers

At Kennington, Bramshill and Ampthill nurseries, experiments were carried out on seedbeds of Japanese larch, Corsican pine and Sitka spruce, testing S.776, a chemical suggested as a post-emergence weedkiller by Shell Chemicals. The material was applied as a spray at 10, 20, 40 and 80 grams in 1¼ gallons of water per 100 sq. yd., (1, 2, 4 and 8 lb. in 60 gallons of water per acre). Weeds were controlled satisfactorily by S.776 at the higher rates of application, but damage to seedlings occurred, the severity of damage being in proportion to the rate of application of the chemical.

Control of Weeds on Fallow Land, Paths, etc.

At Bramshill Nursery, plots treated in 1953 with C.M.U. (3-p-chlorophenyl-1, 1-dimethylurea) at 100, 200 and 400 grams per 100 sq. yd. (10, 20 and 40 lb. per acre) were lined out with Lawson cypress, Sitka spruce, Japanese larch and Corsican pine. The survival of plants on plots treated with C.M.U. at 100 and 200 grams per 100 square yards was similar to that on control plots. On plots treated with C.M.U. at 400 grams few Lawson cypress or Corsican pine survived, while survival of Sitka spruce transplants was significantly lower than on control plots. The survival of Japanese larch transplants was as good as on control plots, but their growth was appreciably poorer.

In another experiment at Bramshill, ground treated with 3-p-chlorophenyl, -1, 1-dimethylurea (C.M.U.) and phenyl-1, 1-dimethyl urea (P.D.U.), each material having been applied at 25, 50, 100 and 200 grams per 100 square yards, was lined out with Sitka spruce, Corsican pine, Lawson cypress and Japanese larch.

Only on plots treated with C.M.U. at 200 grams per 100 square yards was any damage to transplants observed. Here survival of Lawson cypress and Corsican pine was appreciably worse than on control plots; survival of Japanese larch and Sitka spruce on the same plots was good, and was similar to that on the controls.

At Bourne Nursery, Farnham, Surrey, an experiment was carried out on a path round the nursery, comparing weed control obtained from applications of C.M.U. at 100 grams per 100 sq. yd. (10 lb. per acre), "Ureabor" (sodium borates + 4% C.M.U.) at 4 lb. per 100 sq. yards (200 lbs. per acre), sodium chlorate at 4 lb. per 100 sq. yd. (200 lb. per acre) and "Polybor-chlorate" (25% sodium chlorate + borates) at 6 lb. per 100 sq. yd. (300 lb. per acre).

Materials were applied in early July either to the full width of the path or to strips 2 ft. 6 in. wide down either edge of the path. Assessments of weed growth showed that a good initial kill of weeds was obtained with all materials, but that reinfestation with weeds, mainly *Poa annua*, took place quite rapidly on plots treated with sodium chlorate and polybor-chlorate; within twelve weeks these plots had dense weed growth on them. Plots treated with C.M.U. and Ureabor remained practically free of weeds up to the end of the year. It is likely that the rapid reinvasion of plots treated with sodium chlorate and polybor-chlorate was favoured by the continued wet weather during July and August, following the application of weedkillers.

Undercutting Seedbeds 232.326.2

Assessments were made on Scots pine plants from the 1954 undercutting experiments at Tulliallan and Fleet. The seedlings were raised in broadcast beds at Fleet and in drills at Tulliallan. At Fleet the seedlings were undercut at two inches in either March, April, May, June or July of the second growing season, and at five inches in March of the third growing season. Similar dates for undercutting were used at Tulliallan, but lateral cutting of the roots between the drills was also carried out at the time of the undercutting. Seedlings were grown at densities of 16, 32 and 48 per square foot at both nurseries.

Undercut seedlings were between three to four inches smaller than untreated plants, but the date of undercutting did not greatly affect seedling height. Seedling density had only a slight effect on mean heights. Root collar diameter, shoot weight and root weight were all significantly reduced by undercutting, and the lowest density of seedlings had significantly higher root collar diameters and root and shoot weights than the two higher densities.

The number of secondary and tertiary roots over two inches in length were assessed at Fleet. These assessments showed slight but significant increases in numbers of roots of undercut plants, and appreciably more roots on seedlings grown at the lowest density when compared with seedlings grown at the two higher densities.

At Bush Nursery, plants were assessed from an undercutting experiment on oak seedlings which had been grown at a density of ten per square foot, and undercut at depths of either four inches or six inches in July or August of the first year, or March, April, May, June or July of the second year. The assessments showed that undercutting in August of the first year, or March or April of the second year, provided the greatest check to both shoot and root growth, and also reduced the incidence of lammas growth. Undercutting in August or March also reduced the root collar diameter to a greater extent than other treatments. There were no significant differences in shoot or root growth between the two depths of undercutting.

Work on undercutting is still in progress and no definite conclusions can be drawn at this stage.

Maleic hydrazide as a Growth Inhibitor 232.329.9

Seedlings of various species treated in 1954 with foliar sprays of maleic hydrazide of 0.145, 0.290, 0.434 and 0.580 per cent strength, were lined-out at Newton and Benmore as second year seedlings. These seedlings had all suffered a check in growth after the foliar applications had been made. The object of the lining-out extension was to determine whether the check in growth during the first two years was persistent or not.

At Benmore, lodgepole pine, Japanese larch and Norway spruce were under observation. The lodgepole pine transplants treated as seedlings with maleic hydrazide did not produce such large shoots as the untreated plants, and the survival of the treated plants was much lower.

Japanese larch behaved differently, the height growth of treated plants being generally better than that of untreated plants. All seedlings survived transplanting equally well.

Norway spruce plants all grew equally well, except for the plants which received the highest dose of maleic hydrazide, which were appreciably smaller. The survival of plants which received the two higher rates was very much lower than that of plants receiving the two lower rates of application.

At Newton, Scots pine, lodgepole pine and Douglas fir all showed decreases in shoot length in proportion to the concentration of maleic hydrazide applied to the seedlings, the highest concentrations having produced the greatest reductions. All the Scots pine treatments had over ninety per cent survival, but the lodgepole pine and Douglas fir showed a very pronounced reduction in survival when the higher concentrations of maleic hydrazide had been used.

These experiments suggest that maleic hydrazide applied to first year seedlings has an adverse effect on growth and survival of conifer transplants, which is appreciable for at least two years following application.

Seed Dressings—Miscellaneous 232.315.4

Serious losses to both seed and young seedlings by birds are frequently experienced in many nurseries. In the United States of America it has recently been reported that an anthroquinone compound ("Morkit") has very useful bird repellent properties when used in conjunction with an asphalt emulsion ("Indasco"). As a preliminary stage these two materials were used singly and together, and compared with untreated seed and seed treated with red lead for phytotoxic effects on Sitka spruce seed. The experiments were carried out at four nurseries.

None of the five treatments had any effect on seedling heights at any nursery. Seedling yields were not affected by any of the treatments at either Fleet or Benmore, but at Newton nursery seed which had been dressed with the "Indasco" only, or with "Indasco" and "Morkit" together, gave significantly fewer seedlings when compared with untreated seed or seed treated with "Morkit" or red lead only. At Inchnacardoch heathland nursery the "Indasco/Morkit" mixtures also led to significantly lower seedling numbers when compared with other treatments. Bird damage was not reported on any of the plots.

In view of the results at Newton and Inchnacardoch, more work will have to be carried out before continuing with field extensions to determine the deterrent effects of the materials against birds.

Control of Insect Pests 232.327.4

At Kennington Nursery, Oxford, an experiment was carried out testing the phytotoxicity of various insecticides to seedlings of Sitka spruce, and to determine, should a sufficiently large population of larvae be present, the effect of the insecticides on cutworms (larvae of Noctuid moths) of which the larvae of the turnip moth, *Agrotis segetum*, is the most common at Kennington.

Four insecticides were tested, namely (i) Aldrex 30—30% aldrin in a miscible oil—applied at 100 ml. per 100 sq. yd. (1 gallon per acre); (ii) Dieldrex 15—15% dieldrin in a miscible oil—applied at 100 ml. per 100 sq. yd., (1 gallon per acre); (iii) Didimac—25% D.D.T. in a miscible oil—at 100 ml. per 100 sq. yd. (1 gallon per acre) and (iv) Gammalin CL—10% B.H.C. as a miscible liquid at 50 ml. per 100 sq. yd. (½ gallon per acre). All insecticides were applied in 2 gallons of water per 100 square yards (100 gallons per acre). Insecticides were applied in mid-July and mid-August, i.e. at the time of first visible damage by cutworm, and at the time when damage would first appear to be serious, to plots which were isolated one from another by 9-inch polythene sheeting sunk 3 to 4 inches into the ground.

Seedlings killed or cut off by cutworms were counted and picked up daily; Table 7 below shows the total number of dead seedlings picked up for each treatment, from the time of application of insecticides until the cutworms ceased to be active.

Table 7

Cutworm Control Experiments: Kennington, 1956

Insecticide	Total No. of dead seedlings picked up on six square yard plots on Sitka spruce seedbeds: 1st Application mid-July (count over 89 days)	2nd Application mid-August (count over 51 days)
Aldrex 30	16	32
Dieldrex 15	15	17
Didimac	103	90
Gammalin CL	267	507
Control	830	589

It will be seen from this table that best control was obtained by Aldrex 30 and Dieldrex 15. Didimac was not so effective but fairly good control was obtained at both times of application. Gammalin, on the other hand, gave moderate control when applied in July but practically none when applied in August.

There was no damage to seedlings attributable to any insecticide.

Handling of Plants 232.412.4

Investigations aimed at the reduction of losses of plants in storage and transit continued. At Alice Holt Nursery, an experiment was carried out for a second season comparing the effect on survival of plants on various packing materials.

Bundles of fifty plants were exposed for periods of 10, 20 or 30 days protected by either S.600 (a polyvinyl latex which dries to leave a very thin plastic film over the treated parts); paper; polythene or straw and moss. Protection was given either to the roots only or to both roots and shoots.

At the end of the exposure period, bundles were opened, 36 plants were lined out and the remainder used for determination of moisture content.

The mean survival of plants from each treatment are given in Table 8.

It will be seen that period of exposure had relatively little effect on survival and that plants in polythene survived best, straw and moss being almost as good. The latter treatment was more successful this season than in the previous experiment, otherwise the results were substantially the same.

The survival of plants was found to be related to moisture content, as might be expected. The survival of plants with moisture contents of 110 per cent of dry weight or more was over 70 per cent; the survival of plants with a moisture content of 40 per cent of dry weight or less was less than 5 per cent. Between these values survival showed a linear relation to moisture content.

Table 8

Protective Treatments for Forest Plants

Treatment		Survival Percentage		
Protection to:		Exposure period		
Shoot	Root	10 days	20 days	30 days
0	0	4.9	1.1	0.7
0	S.600	1.5	0.7	0.7
0	Paper	0.7	2.2	0.7
0	Polythene	4.4	5.8	6.1
S.600	S.600	5.6	0.7	0.7
S.600	Paper	1.1	6.1	1.8
S.600	Polythene	1.5	14.0	16.1
Paper	Paper	1.5	33.8	18.0
Polythene	Polythene	84.6	88.3	80.9
Straw	Moss	97.6	58.7	75.3

(Means calculated by angular back transformation of the mean of transformed percentages.)

At Alice Holt Nursery an experiment was carried out to determine how long small seedlings of Lawson cypress and Corsican pine could remain out of the ground unprotected, and to test the value both of dipping in S.600 (polyvinyl latex) film over the plant and of polythene bags as means of giving temporary protection during this period. Seedlings were exposed for up to fifty-six hours.

The survival percentage of seedlings which were left unprotected, both of Lawson cypress and Corsican pine, decreased rapidly as the periods of exposure lengthened. Fifty per cent of Lawson cypress seedlings survived about four hours' exposure and 50 per cent of Corsican pine about one hour exposure. Seedlings protected by S.600 withstood exposure a little better; 50 per cent of Lawson cypress survived about six hours' exposure and 50 per cent of the Corsican pine about four hours' exposure. Plants in polythene survived all periods of exposure without any appreciable reduction in survival.

At Wareham Nursery, an experiment was carried out comparing survival of plants in polythene bags with plants packed in straw and moss in the traditional manner.

Plants were tied into bundles of 100 seedlings. Half the bundles were put inside polythene bags. Bales of ten bundles, five bundles in polythene and five not, were then made up using for the outer cover and packing (a) hessian, (b) hessian, straw and moss, (the standard treatment for small lots of plants) and (c) polythene sheet. The bales were then sent by rail to Bush Nursery, outside Edinburgh, and were returned by rail to Wareham, where bales were opened and some plants lined out. The remainder were repacked and sent by road to Alice Holt and were lined out at Bramshill Nursery. The latter plants were in transit for twelve days. The percentage of plants which survived at Bramshill is given in Table 9 below.

It will be seen that survival of plants in polythene, whether as an inner or outer protection, was better than that of plants packed following standard methods.

At Wareham Nursery, an experiment was carried out to determine how long plants could safely remain in polythene bags. Four thousand Lawson cypress

Table 9

Effect of Packing on Percentage Survival

Baled in:	Survival Percentage	
	In polythene bags	Not in polythene bags
Hessian	88%	20%
Hessian, straw and moss	90%	70%*
Polythene	93%	90%

*Standard method

seedlings were bundled and put in polythene bags, samples being lined out at weekly intervals. The survival of plants stored for up to four weeks was excellent and was over 82 per cent; survival of plants stored for up to seven weeks (the longest period of storage) fell to 58 per cent, but this was possibly due as much to lining out very late in the season (May) into dry soil as to deterioration in storage.

SILVICULTURAL INVESTIGATIONS IN THE FOREST:

(A) SOUTH AND CENTRAL ENGLAND AND WALES

By R. F. WOOD and G. D. HOLMES

Afforestation Problems

Age and Type of Planting Stock 232.411

In 1956, the last of the present series of experiments examining the survival and early performance of various grades of Sitka spruce plants was planted at two forests in Wales. This completes a series of eight experiments planted in six forests in Wales in the period 1955 to 1957. These experiments aim at comparing the relative performance of first-year seedlings and one-plus-one, two-plus-one, and two-plus-two transplants, with different planting methods, over a range of upland site conditions, after modern methods of ground preparation.

Ground Preparation and Planting Methods 232.42

Investigations into methods of ploughing on mineral soils were continued in the South on a variety of sites, with the object of gaining a clearer picture of the importance of the form and intensity of cultivation on later crop growth. Recent trials, notably at Haldon, Wareham and Taliesin Forests (see below) have included highly intensive cultivation, involving deep ripping and complete ploughing, in addition to several forms of the more orthodox single furrow ploughing methods. It seems possible that high degrees of cultivation on compacted and impeded mineral soils may prove an economic proposition when judged in terms of subsequent crop increment. The use of the tine plough in place of the older R.L.R. type has proved very successful on Southern heaths, owing to the ability of the deep-going tine point to break up pan and compacted layers in the soil profile, without opening an excessively deep plough furrow.

Trials of a tractor-mounted rotary type "brushcutter" for clearance and preparation of ground for ploughing were most successful. This implement was found capable of razing dense low growth of heather, gorse, and small coppice with ease, the result being greatly improved conditions for ploughing, ensuring complete turnover and solid "lie" of plough ridges.

Mechanical planting trials, using the "Lowther" Planting Machine, were continued. Results indicated that, when mounted on a tractor toolbar, the machine could be used successfully for planting on completely ploughed ground, or for direct planting on uncultivated land, providing the vegetation was not too heavy. Planting on the ridges following single furrow ploughing was much more difficult, but quite possible provided (a) that the ploughing was accurate enough to allow the tracks of the tractor to ride the ridges, and (b) that the ridge was not less than nine inches thick.

At Queen Elizabeth Forest, Hampshire, working on completely ploughed shallow soil over chalk, the machine was capable of planting 12,000 plants per day. The quality of planting was good; end of season survival assessments showing the machine to give similar results to hand planting for beech, while for Corsican pine machine planting gave appreciably higher survival rates than did hand work.

At other centres, one of the most successful methods involved planting in the furrow, following ploughing with a double mould-board two-way-throw plough, fitted with a central tine. This technique could be considered for some mineral soil types, and an attempt was made to modify the machine to allow ploughing and planting in one operation. The plough built on to the machine was not fully satisfactory, and the present development is to take a well-tried double mould-board tine plough and to build on a planting unit.

Afforestation Problems on Particular Types of Land 233

SOUTHERN AND WESTERN HEATHS: CROFT PASCOE, CORNWALL. Work at the small experimental forest at Croft Pascoe, on the Lizard, was continued into its fourth year. Over twenty experiments have been established since 1954, and the area has become a major centre for study of afforestation methods on western heaths. The site is a low, level heath, fully exposed within sight of the sea. The soil, which bears an impoverished vegetation of *Calluna vulgaris*, *Erica tetralix*, *E. vagans*, and *Ulex gallii*, is derived from serpentine rock, a formation on which there is little or no previous experience of afforestation. Investigations have been mainly concerned with methods of ploughing, manuring and provision of shelter, as well as extensive trials of species. The present indications from these trials are encouraging, as many species are establishing themselves more readily than had been expected. Normal single-furrow ploughing has been sufficient to secure rapid establishment of many species, but in one experiment complete ploughing has resulted in considerably increased early height growth of Sitka spruce. Phosphate manures have proved essential for tree establishment and growth under these conditions. Without added phosphate many species survive in a moribund state, but others, notably lodgepole pine and *Pinus radiata*, fail completely. Placed dressings of superphosphate at 2 cwt. per acre, after planting in 1954, has trebled the height growth of Sitka spruce, lodgepole pine, *P. radiata* and *P. pinaster*, and experiments are now under way to examine the response to increased rates of application. The serpentine soil has a low calcium/magnesium ratio, and it is thought that the uptake of potassium and calcium by the plant may be hindered by the excess of magnesium. However, trial applications of calcium carbonate, at rates up to 2 tons per acre, have so far had no effect on the appearance of the crop. Also recent tests of potassium have failed, as yet, to show any significant growth effects.

Broom (*Sarothamnus scoparius*), sown as a nurse crop with some of the first plantings in 1954, is very vigorous, and where phosphate has been applied, forms a dense shrub up to eight feet high after three years from seed. The effect of broom as a nurse is only slight after three years, consisting mainly of an improvement in tree colour. The main impression is that the most promising species, namely, Sitka spruce, *Pinus radiata* and coastal lodgepole pine, thrive well with ploughing and phosphate manuring, and in practice will not require the assistance of a broom nurse to make a crop. Apart from the most promising species mentioned, from the twenty-four under test, it is worth noting that *Pinus pinaster* and *P. muricata* are showing considerable vigour, while *Abies nobilis*, *Cupressus macrocarpa* and *Araucaria* have made a slow but encouraging start.

WAREHAM AND PURBECK, DORSET. Comparative trials of species and preparatory cultivation methods were planted in 1956 on impoverished Eocene sands at Wareham and Purbeck. As reported last year, these trials are an effort to evaluate crop performance, after modern methods of ground preparation, using the best species as indicated by the many existing old species trials. The recent experiments include species comparisons on tine and R.L.R. ploughing at Purbeck, and on highly intensive complete cultivation followed by ridging for drainage; the latter being in one of the most difficult parts of Wareham, on sand overlying impervious impure Kaolin clay.

The Wareham trial made a poor start as severe early frosts killed large numbers of *Cupressus macrocarpa* and *Pinus radiata*, and summer attacks by pine weevil, and heather weevil caused further losses of all species. At Purbeck, comparisons of planting positions of a variety of species, on tine and R.L.R. ploughing, showed markedly better survival from ridge-and-furrow side planting as compared with planting on top of the plough ridge. Differences were especially marked in the cases of red oak, *Tsuga heterophylla*, Sitka spruce, Lawson cypress, *Thuja plicata* and Japanese larch.

A small pilot experiment was established on a difficult fibrous *Molinia* basin peat over impure Kaolin clay at Hyde Bog, Wareham. Drainage and ploughing presented many problems, and with the low rainfall, the tendency of the peat to dry out when thrown into ridges caused concern about plant survival. However, the results of planting in 1956 showed over 90 per cent survival of Sitka spruce, lodgepole pine and Lawson cypress, and the extension of the planting to a practical scale is being considered.

Hill Land in Mid-Wales

COED TALIESIN, CARDIGANSHIRE. As reported last year, a considerable set of experiments was laid down in early 1956, on mineral soils over shale on steep and elevated land in mid-Wales. The site is representative of a considerable area of land characterised by compacted, but relatively fertile, soil on which no experimental work on crop establishment and choice of species has been done. The chief factors limiting tree growth are probably exposure and competition of *Ulex gallii*, heather and grass growth. Experimental work includes detailed and extensive trials of fifteen species, intensity and form of ploughing and subsoiling, and tests of manurial treatments. The wet summer resulted in a very high survival of all species, but it is too early to comment on treatment effects.

Trials of Species 232.11

Species trials have been involved as an important part of investigations on afforestation problems of particular types of land (see above), and in addition numerous species are under test in arboreta and forest plots. A recent development has been to select more promising minor exotic species for simultaneous planting in large trial plots, carried out over a wide variety of climatic and site conditions; such trials allow early assessment of their possible place in our silviculture, and their performance over the country as a whole. The 1956 plantings of *Nothofagus procera* and *N. obliqua* are an example of this type of trial. Considerable importations of seed from Chile in 1953 have permitted the first widespread trials of the two species, which have now been planted on some thirty sites under Research control, and numerous other small plantations have been made, particularly in Wales and North West England.

The climatic range of the planting sites is wide, and an effort has been made to sample as great a variety of soils as possible. The two species have been planted on brown earths of high base content, on poorer brown earth, on calcareous soils and on gleys. Survival has, on the whole, been good, though both species tend to die back after planting, subsequently resprouting from the base.

Mixture Experiments 235.5

Experiments comparing pure and mixed crops of Douglas fir and *Tsuga heterophylla* were planted on three contrasting sites at Mortimer, Herefordshire; Wentwood, Monmouthshire; and Haldon, Devon. The trials were carried out on similar lines to the Sitka spruce/*Tsuga* mixture experiments planted at five forests in 1955. These two species mixtures will be grown to maturity as such, with pure crops of each species as controls. The object is to examine such long-term effects as the yield and quality of produce, and the effects of the mixtures on the site, as compared with each species grown in pure plantation. In addition, a small-scale experiment concerned with enrichment of slow growing pine plantations by underplanting with *Thuja plicata* and *Tsuga heterophylla*, was planted at Beddgelert Forest, Caernarvonshire.

Forest Stand Improvement

Manuring at Time of Planting 232.425

Field work in 1956 was confined to factorial tests of rates of phosphate and potash to newly planted Sitka spruce at Croft Pascoe and Taliesin forests, on site types where there is little experimental evidence on crop responses. Current experiments include studies of rates and forms of phosphate, with tests of potash and magnesium, on the infertile Tertiary sand and gravels at Haldon Forest, Devon.

Improvement of Checked Plantations 237.4

Studies on the treatment of checked and moribund plantations were continued at several forests. Most of the problem areas were planted in the early 1930's on infertile and often impeded soils, without the advantage of modern methods of ground preparation for cultivation and suppression of vegetation. The result in several instances has been plantations in various degrees of growth check, languishing in a dense low vegetation usually including heather and dwarf gorse. Recent experimental work in such areas has involved studies of plant nutrition and vegetation control for improvement of the existing crop, and also trials of clearance and cultivation methods for partial or complete replacement of the crop.

At Wilsey Down, Cornwall, trials started in 1953 on checked Sitka spruce planted in 1934 and 1948, are now showing very striking responses by the crop to recent manuring. Broadcast application of a compound fertilizer containing phosphate and potash in 1954 has increased shoot growth on "checked" trees more than tenfold, as compared with un-manured crops. The size of the growth response was found to increase with rate of application of fertilizer up to 12 cwt. per acre, which was the maximum rate tested. Factorial experiments designed to segregate the effects of phosphate and potash were laid down in 1955, and so far indicate that the growth responses recorded are almost entirely due to phosphate. The phosphate effects are very pronounced for two or three years after application, but it is difficult to say whether the improved vigour will persist long enough to get the crop into canopy. There is evidence that the effect is falling off after two years with application rates as low as 2 cwt. superphosphate per acre, but at 6 cwt. per acre and over there is little sign of the effect falling off within three years of treatment. An interesting point is that heather, dwarf gorse and mixed grasses, which are the main components of the vegetation, show no appreciable response to the dressings. These results are being followed up this year by experiments on fertilizer placement, as compared with broadcast dressings. Also, large scale broadcast dressings of triple superphosphate are being applied, using a tractor-mounted mechanical broadcaster.

The initial success of manuring at Wilsey Down has stimulated similar work on checked areas on other infertile sites. At Wareham, for example, manuring and vegetation control experiments were laid down in 1956 on three pine crops in various stages of growth check in dense heather. So far there is no indication of growth responses to superphosphate broadcast in 1956, but spraying with 2, 4-D has given almost complete kill of heather with negligible damage to the pine crops. Similar work was started in 1956 at Haldon on checked pine in heather, and at Tarenig, Cardiganshire, where Sitka spruce and Norway spruce are in severe check in matted heather and dwarf gorse. In all these cases, 2, 4-D spraying has been most successful in killing the vegetation, but, at present, no growth effects are apparent from this, or from the broadcast fertilizer applications. Other treatments under test for improvement of checked crops include paper mulching, nitrogen manuring by foliage spraying, and soil applications of trace elements. Several such treatments, applied in 1955 to checked Sitka spruce at Ringwood Forest, Hampshire, have so far failed to give appreciable growth effects.

Experiments on methods for complete or partial replacement of checked crops are under way at Wilsey Down, and in 1956 a series of new experiments was started on checked pine areas at Haldon Forest. The soil here is an impoverished badly drained Tertiary sand and gravel formation, with compacted beds of chert and flint impeding rooting. A trial area was cleared, using a tractor-mounted brushcutter, before laying down experiments with six of the best indicated species to examine crop responses to a range of soil cultivation, manuring and vegetation control treatments.

The experiments mentioned have been under way too short a time to permit general conclusions, but there are already pointers to several techniques which can assist in rehabilitation of many crops in a state of growth check.

Manuring of Pole-Stage Crops 237.4

Almost all forest manuring work in Britain has hitherto been confined to treatment of newly planted or checked plantations. Consequently the effects and economics of manuring crops after canopy closure are almost completely unknown. Many practical foresters argue that there can be little justification for manuring at such late stages in crop development, but Continental and recent American experience suggests that some attention must be paid to the question. It seems possible that increased volume increment can more than off-set material and application costs under some conditions. Apart from this, field studies are necessary in order to increase our knowledge of the nutritional requirements of growing crops.

A preliminary experiment testing phosphate, potash and calcium additions to slow-growing Corsican pine at Wareham was completed in 1956, and work is now proceeding on selected pole crops of pine and spruce over a range of site conditions. Initially, the approach is to test broadcast dressings of phosphate, potash, calcium and magnesium on selected infertile sites, with subsidiary trials of forms and rates of nitrogen. These trials are being supplemented by studies of the nutrient levels in treated and untreated crops, to provide data from which it may be possible to define the conditions under which responses are likely to occur.

Chemical Weed Control

Control of Vegetation in Fire Traces 441:432.18

A large experiment was established on firebreaks at three forests in Southern England in 1956. The main object of the work was to assess the value of a selected range of compounds and application rates, as possible means of replacing or supplementing cultivation methods for eradication of perennial grasses and herbaceous species.

Each compound was applied at several rates over a range of soil types, with and without previous cultivation. A total of 124 weed species was covered, including almost all the major species likely to be encountered in practice. A considerable volume of information is now being accumulated on the relative susceptibilities of weed species to compounds. Assessments to date indicate that complete ploughing without chemical treatment is effective in disposing of tussock grasses, and non-rhizomatous herbs, but the majority of weeds, especially rhizome-forming grasses, *Juncus* species, and dicotyledons, regenerate rapidly, particularly on the more fertile soils.

Most of the herbicides tried were selected as being total non-selective plant poisons, with the object of securing a complete kill and maintaining bare soil conditions over the trace for as long as possible. In practice, few compounds accomplished this aim to full satisfaction, although many had useful and persistent effects.

Borax formulations were particularly effective complete weedkillers, especially "concentrated borascu" at rates exceeding 15 cwt. per acre. CMU, which is regarded as a highly persistent complete weedkiller, has been rather disappointing, and rates exceeding 50 lb. per acre were necessary to maintain near-sterile soil conditions for a full season. Sodium arsenite at rates from 1.5 to 6 cwt. per acre gave a high initial kill of almost all species, but recovery was relatively rapid; similar effects followed treatment with sodium chlorate at rates up to 6 cwt. per acre.

Sodium TCA proved highly effective against grasses at rates of 80 lb. per acre and over, but the effect is not persistent for longer than a few months.

The effect of most substances, particularly the boric, arsenic, chlorate, and trichloracetic compounds of sodium, was considerably reduced on calcareous soil. Major differences in cultivation or soil texture had relatively little influence on herbicidal effect.

These experiments are not yet complete, but the results to date suggest that several materials, notably TCA and borax compounds, can be most valuable for such vegetation control, preferably backed up with a growth regulator such as 2,4-D and/or 2,4,5-T for control of woody and deep rooted perennial dicotyledons. Effects have not been as persistent as hoped, but control of regeneration should be possible with much reduced rates of application. The most promising treatments are being extended to enable assessment of the practical implications of the techniques, and several new chemicals, including "Simazin" and "Dalapon", are also under test.

Control of Woody Weeds 441:414.12

A considerable number of trials have been carried out with chemical methods of controlling the wide variety of woody species which may be weeds under certain forest conditions. So far, work has been confined to an experimental scale, with the aim of assessment of the treatment sensitivity of a considerable number of species. Recently, recommendations on the use of these methods have been issued to practical foresters with the aim of encouraging large-scale practical trials. The major part of these recommendations will be found in the Weed Control Handbook for 1957, issued by the British Weed Control Council.

The growth regulator 2,4,5-T has proved the most generally effective material for woody weed control, applied as a foliage spray in water, or as stump, girdle or basal bark treatment in oil. Current experimental work is directed at resistant species, notably blackthorn (*Prunus spinosa*), hawthorn (*Crataegus* species) and rhododendron, with trials of new techniques, notably soil injection with 2,4,5-T, or strip treatment of soil with CMU compounds, in coppice or scrub areas to be planted. The use of growth regulators to clear low growth impeding natural regeneration or planting operations is also under test.

The problem of competition with planted crops by heather and dwarf gorse has been mentioned in discussing treatment of checked plantations. Chemical control of such growth seems a real possibility, and as reported last year, good control of heather can be obtained using 2,4-D at 5 lb. (acid) in 50 gallons of water per acre. This is now under more extensive trial in both checked and newly planted areas. Insufficient evidence is available on the control of dwarf gorse, but experiments are under way to examine the possibilities.

Protection of Seeds and Trees against Damage by Animals

Protection of Direct Sown Seeds 232.336

Direct sowing is a valuable technique for certain species, notably *Pinus radiata* and *P. pinaster*, which often show a poor rate of survival when set out as transplants or seedlings in large scale practice. The chief obstacle in the way of consistent success of direct sowing of such species is the frequently disastrous attack by mice, particularly *Apodemus sylvaticus*. Accordingly, experiments were carried out at Wareham and Croft Pascoe Forests, in 1956, to examine the effectiveness of several chemical repellents applied as seed dressings prior to sowing. The compounds include cyclohexamide (actidione), trinitrobenzine aniline (T.N.B-A) and two compounds tetramethylene-disulphotetramine (tetramine) and a chlorinated hydrocarbon compound (W.R.L.2) provided by the United States Fish and Wild Life Service for trial. Laboratory tests indicated that many of the compounds examined were directly toxic to forest trees and affected the germination of the seed. Among the compounds mentioned the ones exhibiting direct toxicity were cyclohexamide, which killed nearly all seeds, and T.N.B-A which depressed germination to an appreciable extent. The results of field sowings showed that no compound gave complete protection against damage by mice, but W.R.L.2 and T.N.B-A gave seed survival rates of 35 and 22.5 per cent respectively, under conditions where untreated seeds showed a 15 per cent survival. Tetramine was disappointing but warrants further trials. There is good reason to believe that these differences were probably narrowed owing to the fact that the experiment was conducted on a small plot scale, and larger scale trials with these materials are required. The technique of bitumen spraying of sowing spots immediately after sowing, described in the last report, was extended to a larger scale in 1956, with considerable success.

Protection of Planted Trees 451.2:414.14

Experiments were established at Wareham, Quantock and Brightling Forests, and in the New Forest, to test a range of treatments for protection of newly planted hardwoods against damage by roe or red deer. Damage by browsing, bark stripping or nibbling of new shoots has become increasingly common, particularly on red oak, beech and poplar, which were used as the test species in these experiments. A wide variety of proprietary and non-proprietary chemical repellents are under test as bark treatments, or as foliage sprays. In addition, trials were established under enclosed conditions at Alice Holt to determine the phytotoxic effects, if any, of each of the materials under test. A trial of repellents applied to poplar stems at Rogate Forest in 1956, indicated that bone oil and a proprietary compound "Arbinol" gave a high degree of protection for a full season, and seem to have practical possibilities for protection of stems for a period after planting.

Field voles (*Microtus agrestis*) have been responsible for serious damage to new plantings in many parts of the country, and the populations have risen to near-plague proportions in some areas this year. A moderately severe attack on plants in a three-year-old trial of species at Wilsey Down, Cornwall, provided interesting pointers on the species preferences of the beast. Initially, when the population was low but increasing, red oak was extensively damaged by basal bark stripping, but as the population rose, basal gnawing extended to lodgepole pine. Japanese larch was also attacked but damage was almost confined to young shoots and branches. Within the experiment, Sitka spruce, Lawson cypress and *Pinus radiata* were hardly damaged at all. The use of chemical repellents for application in bulk to plants prior to planting is under trial in current experiments at Radnor and Slebech Forests in Wales. Also, recent German work using "Toxaphene" and Endrin as vegetation sprays for poisoning and control of voles has been tested on a small scale, and has yielded results justifying larger scale field trials.

Chemical Bark Peeling 243.8:361.9

As reported last year, large scale application of the best treatment indicated by previous experiments gave disappointing results in terms of reduced peeling costs on pole crops of Sitka spruce, Japanese larch, and Scots pine. Treatment involved application of sodium arsenite (40 per cent As_2O_3) solution to fresh four- to six-inch wide band girdles in late spring. Despite striking success with this on an experimental scale, practical applications resulted in small savings in peeling costs, as the bark was fully freed only over the lower two-thirds or so of treated stems. The reasons for this failure are not fully understood, but recent American work suggests that a four- to six-inch girdle may be too narrow to allow retention of sufficient solution to ensure a rapid and complete kill of cambium cells, for the whole way up the tree. This point will be examined in new experiments.

Trials of chemicals with a lower mammalian toxicity than sodium arsenite were completed in 1956, and polybor-chlorate, sodium pentaborate, and sodium chlorate, 3-amino triazol, proved completely ineffective for bark peeling purposes for Sitka spruce, European larch, Scots pine and aspen, which were selected as test species. Sodium pentachlorphenate however appears promising on Scots pine and aspen, but had little value for the other two species. An interesting result was that 4 per cent 2,4,5-T butyl, iso-butyl ester, in oil as a basal bark spray, greatly improved the peeling properties of European larch, Scots pine and aspen. Sitka spruce failed to respond appreciably to any of the materials tested. Sodium arsenite remains the outstanding material for bark loosening by stem treatment, and recent experiments on dates of application indicate that it can be applied with effect any time within the period late May to early August. The effect of increasing girdle width in extending bark loosening to the top of the stem remains to be investigated. Preliminary studies were also completed using the "Wilcox" bark peeling gauge to assess natural variations in bark looseness over the season for oak, beech, Scots pine, Corsican pine, Japanese larch, Norway spruce, Sitka spruce and Douglas fir. First results indicate close similarity between species in the resistance to peeling in the season of sap rise, but considerable differences in the pattern of peeling resistance over the season. It is necessary to repeat these observations over several seasons before general conclusions can be made.

SILVICULTURAL INVESTIGATIONS IN THE FOREST: (B) SCOTLAND AND NORTH ENGLAND

By M. V. EDWARDS, G. G. STEWART and R. LINES

Trials of Species 232.11:233

Comparisons of the growth of different species, both on a single site and over a range of different sites, continue to be one of the most important branches of silvicultural research work. Many other experiments which were concerned with details of afforestation technique and have now fulfilled their original purposes, are being used for long term studies of the species concerned. Detailed records of the histories of such crops are available, and a good deal is known of the locality factors both before and after planting.

Further examinations of the distribution of the roots at the boundary between two species were made, to study the "nursing" of one species by another, and it is becoming increasingly clear that Sitka spruce is "nursed" by other species to the extent that such species eliminate heather, *Calluna vulgaris*. In any one site, however, there is a complex of interacting factors which cannot easily be unravelled.

Afforestation Problems

Heathland 232.11:233

In parts of the country where there are large areas of comparatively uniform land, and where only one or two main species are widely used, for example Scots pine on upland heaths, experiments to try to find suitable alternative species have been laid down over the past few years. Two trials have been established at Rosedale Forest, Yorkshire, where pines were the main species first planted, using both conifers and hardwoods.

Early attempts to afforest the more compacted heathland sites by planting directly into the surface of the ground usually resulted in a sparse crop of stunted trees. The rehabilitation of such an area of Scots pine has been commenced in the Black Isle, Ross-shire; complete ploughing will be compared with tine ploughing, using Scots pine, Douglas fir, and Japanese larch. A trial of fertilisers (nitrogen, phosphorus, potassium and calcium) has been incorporated into the experiment.

Peatland 232.11:233

Because of its nitrogen-fixing ability, alder is believed to be a valuable tree for poor quality sites, and attempts to grow alder were made in the early experiments at the Lon Mor in Inchnacardoch Forest and elsewhere; these experiments were not very successful. A trial using the present peatland technique of planting on closely-spaced plough ridges has been made this year, with three species of alder, pure and in a group mixture with lodgepole pine.

Pilot plots on Limiting Sites 232.11:233:425

Recent experience in the Pennines has underlined the problems of afforestation where exposure, infertile soil and atmospheric pollution make conditions very difficult. Two trials which test a large number of species, including hardwoods, have been established at Hebden Royd Forest, near Halifax, Yorkshire, one on a very exposed deep peat area and one on a more sheltered site of former pastureland. On the latter site, three types of ploughing, including complete ploughing, are being compared, as well as the effects of nitrogen, phosphorus and potassium fertilizers.

On an exposed sea-coast site near Lael Forest in Wester Ross, two plots totalling fourteen acres in area were planted. One of the plots was mainly on thin peat overlying a very hard stony soil, and the preparation of this ground by ploughing was especially difficult. The tine plough was used and stood up to the work very satisfactorily. Various species have been planted in a matrix of lodgepole pine, and all have started well.

Two other plots, each of about four acres, have been planted at Spadeadam Forest, Cumberland, on one of the large deep peat bogs which are common in this area. Again, various species have been planted in a matrix of lodgepole pine.

As is well known, the Muir of Rannoch, on the borders of Argyll and Inverness-shire, is one of the largest and most desolate moors in Scotland. This year a ten-acre plot at the western end of the moor was ploughed and planted. The ground covered by the plot consists of rounded peat-covered knolls interspersed with deeper peat flats, both with many outcrops of rock not submerged by the peat, and the area is typical of a large part of the fringes of Rannoch Moor. A number of species has been planted, mainly in mixture with lodgepole pine.

Growth in the older pilot plots is variable, depending on how combinations of poor soil and exposure affect the young trees. Most of the plots are promising, but some on the poorest sites are only just holding their own; the most exposed plots in Caithness and the Orkney Island of Hoy are in this latter class.

Manuring in the Forest 232.425.1

A few more trials of triple superphosphate have been commenced. Triple superphosphate, in place of ground mineral phosphate which is commonly applied to individual trees immediately after planting on the poorer peat and heath sites, has been used experimentally for three years. So far survivals with each fertilizer have been similar, which is encouraging in view of the disastrous results which a proprietary brand of superphosphate sometimes gave in trials twenty years ago. It is suspected that the method of placing the fertilizer in relation to the roots of the plants is of the greatest importance, and this is being investigated.

One further long-term trial to test the effect of phosphate on timber production, on a site which would not normally be considered poor enough to receive a phosphate dressing, has been laid down at Langdale Forest, Yorkshire.

Draining 237.2

Attention is constantly being paid to the drainage of peat and heavy clay soils, where unsatisfactory conditions are often brought to notice by windblow. Investigations on the deep peat at Inchnacardoch Forest are being carried out by the Macaulay Institute, Aberdeen, and studies have been made on boulder clays in the deep draining experiments which have already been established. An extreme example of the failure of roots to penetrate clay, and of the onset of unhealthy conditions in the crowns of the trees at about the time of first thinning, has recently been investigated, and is focussing attention on the difficulties of afforesting shallow soils over clay.

Thinning 242

Within the last few years a method of heavy crown thinning has been developed in the South Scotland Conservancy, which appears to have certain advantages over the light crown thinning which has been used on a small scale in different parts of the country for many years. An experiment has been started in a Norway spruce pole crop at the Forest of Ae, Dumfriesshire, to compare this heavy crown thinning method with what might be said to be the "standard" practice of a moderately heavy low thinning (C/D grade).

Spacing and Pruning 232.43:245.13

Considerable progress has been made in the assessment of the spacing experiments planted about twenty years ago. These experiments are now being treated in three different ways, and one of the methods includes pruning. This work, and the examination of the data of old experiments on pruning, indicates that too late a start has usually been made, with the inevitable result that the unpruned core of the tree is needlessly large in diameter. In new experiments, including some in combination with different thinning methods, which have already been referred to, an earlier start is being made. The object is either to remove trees of bad form or to prune the most vigorous trees, before the bad trees have done harm or the vigorous trees have developed a large bole.

Comparison of Pure and Mixed Crops 235.5

New mixture experiments, using western hemlock and Douglas fir, were established in a number of forests, in Scotland at Yair Hill, Selkirkshire, and in England at Hamsterley, County Durham. The plan for these experiments follows that used in previous years, and involves the use of half-acre plots arranged in a balanced incomplete Latin square. The broadleaved species in a mixture experiment established in 1955, in conjunction with the Nature Conservancy at Gisburn Forest, Yorkshire, were badly damaged by voles and by insect pests during the winter of 1956, and very heavy beating up will be necessary. The conifers used there—Scots pine and Norway spruce—have not yet been attacked.

Studies in Forest Meteorology

Atmospheric Pollution 425.1

The level of atmospheric pollution in country districts of the industrial region of the Pennines is often high, and the extent to which it affects tree growth there has largely been a matter of conjecture. The poor growth of trees in some of these areas has been attributed variously to poor soil, exposure and atmospheric pollution, and it was in an attempt to separate these factors that a series of lead peroxide stations were set up during the summer of 1956. These stations have been erected and are maintained very largely by the generous co-operation of the various Water Boards on whose land they are situated. In addition some are on private estates, and others in Forestry Commission woodlands. The sites were carefully chosen in consultation with local staff, so that comparisons can be made between the results of the chemical analysis for sulphur dioxide and the growth and health of various tree species adjoining the stations.

The project is essentially a fairly long term one, as the figure for atmospheric pollution in any one month varies from year to year. The pattern of the variation, however, is less variable, and it is hoped that the records of about three years will provide sufficient information about the degree of atmospheric pollution at each locality to provide a pointer to the level of pollution above which afforestation is likely to prove unrewarding. Using the records of the many stations maintained by urban bodies, it is possible to get a complete range of the level of pollution from the town centres, where few tree species will survive, outwards towards the suburbs where a number of broadleaved species can be grown and so to the uplands where there are few existing records and the deposit of soot on the needles has hitherto been the foresters' only guide.

Records will be made of the various site factors including soil, aspect and exposure, and the assessment of this last factor will be helped by using anemometer and exposure flag records (see below).

Estimation of Exposure by Flags 421.2

Exposure is a factor which is well known to be of great importance in British forestry, and now that modern techniques of establishment allow trees to be planted on land thought unplantable twenty years ago, the planting limit is likely to be governed to an increasing extent by exposure. Assessment of the comparative exposure of a site which has not borne trees for hundreds of years poses many problems, and it was to throw light on this difficult subject that in 1954 a number of flags were set up in our pilot plots in north Scotland. The idea came from Orkney, where many years ago the owner of an estate set up unhemmed flags in a number of likely places and returned some time later to build his house on the site of the flag which was least tattered.

The current experiment is an attempt to correlate the growth of trees in the older experimental areas (where trees have been growing for twenty-five to thirty years) with the new pilot plantations, where trees may grow well while they are still in the shelter of the plough ridges, yet never reach normal dimensions when they grow up into the blast. The method is to expose small unhemmed flags of standard specification cotton cloth for a period of two or three months. All the flags are put out at the same time and, after exposure, they are all called in together and the area remaining untattered is measured. After several periods of exposure it was soon clear that the worst of the new pilot plantations in Caithness, Orkney and Shetland were in a different class of exposure, as reflected by flag tattering, to the older experimental areas such as Teindland, Morayshire, and the Lon Mor, Inverness-shire. The northern flags were often three or four times as tattered as those at the latter site.

It is probably too much to hope that any very exact results will ever come from such a crude apparatus, but there has been a fair degree of consistency in the order of tattering of the different flag stations, and work is proceeding in an attempt to correlate the rate of tatter of a standard flag with the periodic readings of an anemometer recording the run of wind in miles. There are, of course, theoretical objections to the scheme, such as the effect of differences in precipitation, differences in sunlight, constant winds as opposed to occasional fierce gales, etc., but if it is found that the growth of trees in the pilot plots parallels the tattering of the flags, then a useful tool for evaluating exposure will have been discovered. It seems, in fact, as though the flags will only give satisfactory guidance where the exposure is so severe that it overshadows all the other factors which cause flags to disintegrate.

DERELICT WOODLAND INVESTIGATIONS

By A. D. MILLER 25

During the year, work on the series of experiments established during the previous seven years, to compare the costs incurred and the quality of the crops produced by different methods of treating the principal types of British derelict woodlands, has been confined to maintenance and assessment. This project has now reached the stage when a number of conclusions can be drawn, and a review will be published in due course.

Trials of mechanical scrub clearance have continued, and the following conclusions have been drawn about the performance of various machines, all of which were powered by tracked tractors.

(1) Grubber Blade

A toothed digging blade mounted on a tractor of 46 to 106 drawbar horsepower designed to remove the root systems. This is a reliable tool which will always achieve a satisfactory standard of clearance, and also a degree of soil cultivation, which is generally valuable. However a good deal of earth always finds its way into the heaps of debris, and this raises the cost of burning and lowers the standard of the finished work. Also, in impervious soils the pockets left by displaced roots and stumps fill with water and cannot easily be drained. One machine will clear about an acre per day, and the total costs of clearing and burning average about £30 per acre. On the basis of these costs and rates of work the grubber blade must be regarded as only marginally efficient.

(2) The "Sabre" Cutter

A circular saw mounted on a hydraulically controlled boom in front of a small tractor. Scrub stems are cut at ground level and the soil is not disturbed, so that subsequent burning is straightforward. This machine achieves a high standard of cutting and the ground is left in a good condition, but the main disadvantages are the rather slow rate of work, not more than half an acre can be cut per day, and the cost, which is around £32 per acre for clearing dense scrub. The sight and sound of the unprotected saw are also somewhat alarming, though no accidents have been reported.

(3) The "Fleco" Tree Cutter

A horizontal cutting blade fixed to a 35-45 D.B.H.P. tractor and using its momentum to chisel through the scrub stems at ground level. This is quite an efficient device and reaches a good standard of clearance with little disturbance to the surface soil, although a number of stumps become uprooted and carry soil into the heap of debris. This tool can be used in a number of different ways, either to cut and push the debris into heaps or windrows in a single operation, or to cut the growth and leave it scattered to be swept up by a second tractor carrying a rake. There is a suggestion that the former method may be a little cheaper, and when used in this way a single machine will deal with an average of 1½ acres per day, while the second method involving two tractors nearly doubles this output. The costs of using this machine have varied somewhat, but the total expense of cutting and burning should be between £20 and £25 per acre.

A disadvantage of this cutter is that, being set squarely across the front of the tractor, the impact due to cutting substantial stems is borne by the transmission system of the tractor, and has been the cause of undue wear and damage to the machine.

(4) The Anchor Chain

The Anchor Chain is fixed between two tractors of 66-106 (or over) D.B.H.P. The tractors are driven through the scrub on parallel courses 15 to 20 yards apart, and 100 to 150 feet of anchor chain is allowed to form a loop behind them. As the tractors are driven forward the chain should break or uproot all the woody growth between them. Under rather special conditions this method has great potentialities for scrub clearance, but where these conditions are not met it is generally unsuccessful. The requirements for efficient work by this method are:

(i) A light soil from which woody root systems can be torn easily, and which does not adhere strongly after the scrub has been uprooted. A heavy soil has too strong a hold on the roots to allow this system to work well.

(ii) The stems of the scrub growth must be stiff enough to stand up to the chain, so that sufficient pull can be exerted to drag the roots out of the ground. Flexible stems merely bend and the chain rides over them.

Where these conditions are met the initial clearance is very fast, and two tractors will cover the ground at the rate of about three acres per hour. The action of the chain is such that it tends to collect much debris in the loop, and sheds this load every few minutes, so that the material is very roughly piled. Hence it is usually necessary to use a tractor-mounted rake to complete the heaping and to assist with burning. The success of the latter operation is very dependent on the weather, and on the moisture content of the woody debris, but under average conditions a further two to three tractor-hours per acre will be involved. A good deal of soil is invariably carried into the heaps, and this makes burning more difficult, but this disadvantage is more than offset by the high speed and low cost of the initial chaining.

This method has been used with success on dense old rhododendron growing on a gravel soil and dense old hawthorn (*Crataegus* species) on a chalk downland, where the two requirements of light soil and stiff stems were met. But when used on a hazel-birch-oak-aspen association on a heavy clay soil, scarcely any of the root systems were pulled out of the soil, and the method failed.

(5) **The V-Blade Scrub Cutter** (see Plate 1)

This is the most promising scrub-cutting device so far tested. It consists of a substantial blade shaped rather like a snow plough but with sharp, horizontal, cutting edges fitted at the bottom of the structure. The blades tested have been fitted onto a Class I tractor (over 106 delivered horse power), and in operation the cutting edges are kept as near as possible to ground level. As the tractor is driven forward, the action of the cutter is to slice through the scrub stems and coppice stools and to push them to one side, so that the machine can be moved forward continuously without building up a pile of debris in front of it. The slicing action of the V-blade allows the machine to cut through stems up to 9 to 12 inches diameter, and also to deal with very substantial coppice stools because these are usually hollow or of irregular growth; also the shock to the transmission system of the tractor is much reduced.

An important advantage of this cutter is that it need not be used to clear cut all the scrub, but, where desired, it can conveniently leave a degree of overhead cover to shelter the new crop and to maintain some of the benefits of woodland conditions. Also where local markets are favourable, firewood or other saleable items can be salvaged from the debris at a profit, while the remainder may either be burned or left on the ground to rot.

Apart from the size of the stems to be felled, the most important single factor affecting the efficiency of the V-blade cutter is the texture of the soil. On heavy or clay soils which hold the scrub root systems firmly enough to allow the stems to stand up to pressure of the cutting edges, this device works extremely well and cuts very cleanly at or about ground level; on lighter soils, however, some of the less firmly rooted stems may be plucked from the ground and a small degree of soil disturbance results. This may not matter in itself but is apt to add to the costs and difficulties of subsequent burning or tidying operations.

The rates of cutting naturally vary a good deal with the type and condition of the scrub to be cut. When cutting rather light birch scrub 7 to 8 feet tall at Sherwood Forest, Nottinghamshire, some 45 acres were cut at an average rate of about 1½ acres per hour; the brush was then pushed into windrows by a tractor-mounted rake at the rate of about an acre per hour. The windrows were not burned on account of the local fire risk. In much more difficult conditions at

Wentwood in South Wales, on a steep hillside where gradients of 1 in 4 were common (and where one bank was found, after clearance, to have a gradient of 1 in 2) and where the soil was a very loose silty sand and the weather continuously wet, just over 200 acres were cut at an average rate of 2 hours per acre, and the debris was pushed into big windrows some 2 chains apart at a similar rate. A good deal of the very loose soil found its way into the windrows but, rabbits being absent, no attempt was made to burn the debris. Had burning been necessary it would, under those conditions, have added appreciably to the cost.

An improved model of the V-blade cutter was recently fitted to a caterpillar D8 tractor, and two sites totalling 100 acres have been treated principally by cutting a series of strips through the scrub. The object of this is to maintain sheltered conditions for the new crop, and two patterns of strips have been tested. First were strips a single width of the cutter, that is about 12 feet, separated by hedges of uncut scrub about 6 feet wide. Secondly strips about 22 feet wide were cut, also leaving uncut hedges about 6 feet wide. The 12 feet wide strips separated by a narrow hedge leave conditions not very dissimilar from a uniform thinning in the scrub (see Plate 2). The gradients involved on these sites were quite moderate, but the scrub was tall and dense; however the strip cutting proceeded at an average rate of rather more than an acre per hour. At the time of writing, the second phase of tidying up has not been started, and it is planned to compare a number of different approaches. It is not expected that this phase will involve more than 1 or 2 tractor-hours per acre, so that the total costs of preparing the ground for planting should be £12 per acre or less. This compares very favourably with the costs of hand cutting and, of course, reduces the requirements for hand labour markedly during the stage of preparing the ground.

Thus most types of woody scrub can be treated successfully either by the anchor chain or the V-blade, with the latter tool having by far the greater application. However the costs of moving one or more Class I tractors to a site means that it is scarcely economic to use these methods on areas of less than twenty acres, and there is still scope for the development of a light tool which can be moved cheaply to deal with the many scrub woodlands less than twenty acres in extent.

PROVENANCE STUDIES

By R. LINES and J. R. ALDHOUS

Lodgepole pine 232.12

In the Report on Forest Research for 1956, the collection of seed from stands of lodgepole pine (*Pinus contorta*) growing in Great Britain and Ireland was described. Stocks raised from these seeds are being planted at Achnashellach, Wester Ross (rainfall 80 ins. and over); Elchies, Moray (rainfall 35 ins.); and Ceiriog, Denbigh (rainfall 55 ins.). The last site is an elevated peat bog.

Also available are seedlings from a considerable range of origins in Western North America. It is proposed to use some of these provenances in experiments in mid-Wales and south-west England, on sites where fortuitous comparisons of seed origin suggest that the provenance factor in lodgepole pine is highly critical.

For several years a common source of "coastal" lodgepole pine for the

Forestry Commission has been Lulu Island, British Columbia. The fact that this provenance does not grow with the great vigour and hardiness associated with other "coastal" provenances was apparent only after it had been used for two or three years, and in many trial plantations. At Strathy, Sutherland, a provenance from the coast of Washington, U.S.A., was used in the 1949 and 1950 experiments, while in the succeeding year the Lulu Island provenance was used. Growth has been much faster and needle colour is better in the earlier years' planting. Experience at many other sites has shown that the Lulu Island provenance is definitely inferior, and cannot be considered a typical "coastal" provenance either in vigour or in resistance to exposure.

Sitka spruce

Interest has continued in the Alaskan provenances of this species. In 1956 a substantial quantity of seed became available from Cordova, which is not far from the north-western limit of the species in Alaska. In Scotland seed of this origin was sown at three nurseries in comparative experiments with seed from Queen Charlotte Islands (which is the standard source of seed for Britain) and seed collected from trees at Inverliever, Argyll. The original provenance of the latter trees is not known; it is however, likely that they are of Washington origin. The nurseries were Tulliallan heathland nursery, Fife; Fleet, Kirkcudbrightshire; and Inchnacardoch, Inverness-shire, and the results obtained at the end of the first year are shown in Table 10.

Table 10

Provenance Comparisons of First Year Sitka Spruce Seedlings

	Mean Height inches			Mean
	Tulliallan	Fleet	Inchnacardoch	
55/3 Cordova	0.90	0.56	0.34	0.60
55/805 Inverliever	2.53	—	0.86	1.69
53/663 Queen Charlotte Islands	1.64	0.87	0.74	1.08
Standard Error	0.10	0.05	0.04	—
Difference necessary 5%	0.30	0.18	0.12	—
for significance 1%	0.42	0.29	0.17	—

It will be seen that the provenance which has made the best growth is Inverliever, while the Cordova plants have done very poorly indeed, not reaching one inch in height at any of the three nurseries. In addition, at Inchnacardoch, some of the Alaskan plants suffered frost damage in autumn.

Comparisons of the Cordova and Queen Charlotte Island provenances in the seedbeds at Wareham, Dorset yielded similar results to those in the Scottish nurseries.

In a provenance experiment planted in 1950 at Glendaruel, Argyll, an assessment of the incidence of "lammas" shoots shows that such late growth is much commoner on Sitka spruce of Washington origin than on that from the Queen Charlotte Islands. Similar observations have been made on parallel experiments at Gwydyr, Caernarvon, and Kielder, Northumberland.

Hybrid larch

In the Report on Forest Research, 1951 (p. 40) experiments at Drummond Hill, Perthshire, with hybrid larch of various generations and from different parent-stands were described. As these experiments were planted with replicated small plots their useful life only lasted until the trees of adjacent plots began to interfere with one another. They have therefore had a final assessment and the results are shown in Table 11. There is no apparent superiority of the first

Table 11

Basal area production of three generations of Hybrid larch. Drummond Hill Forest

Planted 1936 — Basal area in square feet

Provenance	Basal area of 30-plant plot, Autumn 1951		
	Main Crop	Thinnings	Total basal area production
Probably first generation Glamis	1.5	0.6	2.1
Second Generation:			
Dalmarnock (Dunkeld)	1.3	0.7	2.0
Whitegate (Dunkeld)	1.1	0.6	1.7
Killiechangie (Dunkeld)	1.4	0.7	2.1
Newtyle (Dunkeld)	1.5	0.7	2.2
Lower Warren (Dunkeld)	1.3	0.6	1.9
Third Generation:			
Ladywell, Dunkeld	0.9	0.2	1.1
Standard error of the mean	±0.1	±0.1	±0.2
Difference necessary for significance at 5%	0.4	0.3	0.5

Table 12

Basal area production of two generations of hybrid larch. Drummond Hill Forest

Planted 1936 — Basal area in square feet

Provenance	Basal Area of 30-plant plot, Autumn 1951 and Jan. 1956			
	Main Crop	1st Thinning	2nd Thinning	Total Basal Area Production
Probably second generation Glamis grade I plants	3.18	0.5	0.72	4.40
Second Generation:				
Dalmarnock (Dunkeld)	2.26	0.1	0.36	2.72
Whitegate (Dunkeld)	2.12	0.5	0.46	3.08
Killiechangie (Dunkeld)	1.69	0.2	0.80	2.69
Newtyle (Dunkeld)	1.74	0.5	0.52	2.76
Lower Warren (Dunkeld)	1.42	0.6	0.46	2.48
Third Generation:				
Ladywell, Dunkeld	1.36	Nil	0.28	1.64

(Mean of two replications)

Table 13

Volume production of two generations of hybrid larch. Cardrona Forest

Planted 1937 *Volume in Hoppus Feet*

Provenance	Volume production of thinnings per plot Autumn 1951 and April 1955		
	1st Thinning	2nd Thinning	Total Production from Thinnings
Probably second generation:			
Glamis Grade I plants	10.0	9.5	19.5
Second Generation:			
Dalmarnock (Dunkeld)	6.9	7.2	14.1
Whitegate (Dunkeld)	6.6	4.5	11.1
Killiechangie (Dunkeld)	6.4	5.2	11.6
Newtyle (Dunkeld)	6.4	6.0	12.4
Lower Warren (Dunkeld)	6.9	6.1	13.0
Third generation:			
Ladywell, Dunkeld	3.9	5.5	9.4
Standard error of the mean	±0.9	±1.0	—
Difference necessary for significance at 5%	2.6	2.8	—

generation over the second generation hybrid on the criterion of basal area, but the third generation is significantly poorer. This is confirmed by an extension of the same experiment (planted 1937) which has had two thinnings (Table 12), and by a further experiment at Cardrona, Peeblesshire, where the same lots were planted and have also had two thinnings (Table 13).

From Tables 12 and 13 it will be seen that the second generation trees from Glamis, Angus (which were selected for vigour in the nursery) have grown outstandingly well, while the plots of the third generation from Ladywell were hardly ready for thinning in 1951 and were still poor in 1956. The differences between the lots which come from the Dunkeld region are not significant.

The experiment testing the performance of various grades of Dunkeld hybrid larch (Broxa 81) which was noted in the Annual Report on Forest Research for 1951, was assessed three years after planting and the results noted by M. V. Edwards in *Forestry* XXIX (1). There were no significant height differences then. At six years of age the plants classed as resembling the Japanese parent most closely were highly significantly less tall than those of a more typical hybrid appearance. There was no significant difference in height between the plants of the truly intermediate hybrid and those hybrids that resembled the European parent.

European larch

In the Report on Forest Research, 1951 (p. 38) an experiment was described with ten provenances of European larch from the Alps, Silesia and Scotland. Five years later when the trees were nineteen years old a thinning was made and another height assessment carried out. As will be seen from Table 14 most provenances have made good growth in the five year interval and have put on an additional ten feet or more. There is little change in the order of merit for height growth, only the Glentress provenance has improved from ninth to fifth place.

The Silesian provenance "Zulzhoff", which is of guaranteed Sudeten origin, was in need of thinning by October 1951 and this was carried out, but none of the other provenances required thinning until March, 1956; in fact, even then the French Alps provenance was not ready for thinning. This was partly due to the initial poor survival of plants of this provenance.

Table 14

Characteristics of European larch of Various Provenances

Drummond Hill, Experiment 8

Provenance	Mean Ht. 14 yrs. feet	Mean Ht. 19 yrs. feet	Mean No. of stems per plot		Basal area of plot, sq. ft.	
			Maincrop	Thinnings	Maincrop	Thinnings
German						
Zulzhoff, Silesia	29.8	42.6	9.5	2.5*	2.12	1.30†
Scottish						
Tom-an-Uird, Morayshire	24.8	38.4	9.8	7.8	1.51	0.90
Advie, Morayshire	22.8	36.4	11.2	6.8	1.78	0.48
Glencoe, Argyll	24.5	38.3	12.0	9.8	2.52	1.05
Glentress, Peebles-shire	20.2	35.2	10.8	7.8	1.79	0.69
Tulliemet, Atholl, Perthshire	21.5	33.9	11.5	7.2	1.77	0.53
Loch Kennard, Perthshire	19.5	30.2	9.8	4.2	1.26	0.26
Loch Ericht, Inverness-shire	20.2	34.3	10.8	7.2	1.64	0.51
Alpine						
Central Alps 2,300-3,300 ft.	22.7	34.8	9.2	6.2	1.60	0.45
North Tyrol 1,900-2,600 ft.	21.5	34.0	10.0	3.5	1.76	0.32
French Alps 2,800 ft.	14.4	24.7	11.5	Nil	1.00	Nil
Standard error of the mean	±0.9	±0.9	Differences analysed after transformation but not significant.		±0.17	±0.11
Difference necessary for significance 5%	2.6	2.6			0.50	0.31
1%	3.5	3.5			0.67	0.42

*Removed in second thinning. †Two thinnings.

Thinning has now brought about approximate equality in the numbers of trees per plot, so that it is interesting to note the wide and highly significant variation in the maincrop basal area after thinning. The high production of the Glencoe provenance is partly a result of its 94 per cent survival, which was better than that of any other provenance.

In 1952 a number of provenances of European larch, and also of hybrid larch, were planted on several sites where "Larch die-back" had occurred in older crops (see Report on Forest Research, 1952 and 1956). Experiments on two such sites at Coed y Brenin, Merioneth, were assessed early in 1956. On the Dolgoed area at Coed y Brenin, growth was good. Hybrid larch from Inver Wood, Dunkeld and Polish larch from Skarzysko had both exceeded six feet in height, the Polish larch being slightly taller. Larch from Münsterthal was poorest in growth, followed by two Scottish provenances and a provenance from Hesse, Germany. Sudeten larch from Hruby Jesenik, Moravia, was intermediate in height between the best Scottish provenance and the hybrid larch.

On the Pen y Bryn area at Coed y Brenin, there was a similar pattern of height growth, but the general level of growth was much less than at Dolgoed. Hybrid larch was the tallest but had not reached four feet in height. Polish larch was not planted on this site.

Survival on both sites was good. At Pen y Bryn there were no differences between provenances in this respect; at Dolgoed the Münsterthal provenance was the worst, while the survival of Polish larch was particularly good. Canker was already present on trees from Münsterthal.

Pinus nigra

Assessments were made in 1955 and 1956 of two experiments both planted in 1952 comparing provenances of *P. nigra* from East England; Corsica; Calabria, Italy and Cuenca, Spain. One experiment is on sand dunes at Newborough Warren, Anglesey and the other is at Clocaenog forest, Denbigh on a grass/*Ulex* site at 1,200 ft. Results of assessments of survival and growth are given in Table 15.

Table 15

Pinus nigra. Height and Survival. Planted 1952

Provenance	Survival Percentage		Mean Height feet		
	Clocaenog 1955	Newborough 1956	Clocaenog 1955*	Newborough 1956	
East England (48/12K1)	81	89	1.7	3.2	Standard Error ± 0.16
Calabria, Italy (49/3)	97	96	2.1	2.9	
Corsica (48/40)	82	94	1.4	3.2	
Cuenca, Spain (49/228)	80	75	1.2	2.4	

*Height at end of 1954 growing season.

The Calabrian provenance, particularly at Clocaenog, is notable for its foliage which is dense and deep green in colour; on this site, which most foresters would now consider too high for Corsican pine, this provenance shows much promise. At Newborough, on a site well suited to Corsican pine, there is little to distinguish the performance of the provenances from East England, Corsica and Calabria, though the foliage of the Calabrian provenance remains darker green than that of other provenances. The provenance from Spain is inferior at both sites.

Pinus ponderosa

At Thetford Forest, Norfolk, an experiment planted in 1930 comparing six provenances of *Pinus ponderosa* all from British Columbia, was assessed at the time of the first thinning, with results shown in Table 16.

Table 16

Pinus ponderosa, Height and Basal Area. Age 26 yrs. October, 1956

Provenance	Elevation Feet	Main Crop After Thinning: Average Ht. Feet	Basal Area Hoppus Sq. Feet
Lillooet	800	32	98.3
Lytton	700	31	88.9
Salmon River	2,200	29½	89.6
Enderby	1,200	34	81.1
Seton Lake	800	30½	87.3
Tappen	1,300	29	76.0

It will be seen that the differences in height are small. The yield from thinnings ranged between 390 and 500 Hoppus cubic feet per acre from all plots, except Tappen. This plot had the poorest stocking of all and very few trees were removed in thinning. The assessment support the conclusion that there is little to distinguish these provenances at Thetford.

Table 17

Scots Pine Provenance Experiment, Thetford. Mean Height and Basal Area

Group	Provenance	Latitude	Year of Planting	Height of 100 Largest Trees per Acre feet	Basal Area Hoppus Feet Per Acre	Rank by Height 1956	Rank by Height 1949
I Home Provenances	East England	52°N	1932	36.5	83.7	5	2
	Loch Maree	58°N	1932	32.0	84.6	12	12
	Glengarry	57°N	1932	30.7	80.7	17	17
	Cawdor	57°N	1932	34.0	79.0	9	8
	Cawdor	57°N	1934	32.0	80.9	12	20
	Darnaway	57°N	1932	32.0	81.9	12	7
	Glenmoriston....	57°N	1932	28.8	80.2	20	18
II Middle Rhine and Central Germany	Wangenbourg, Bas Rhin	49°N	1933	36.7	87.9	4	4
	Hanau, Northern Vosges	50°N	1933	37.3	84.3	3	3
	Kassel, Hesse	51°N	1933	38.2	87.0	1	10
	Hagenau, Bas Rhin*....	49°N	1933	38.0	91.3	2	1
III Southern Central Europe	Lenti, Hungary	47°N	1932	32.5	68.8	11	5
	Sopron, Hungary	48°N	1932	34.2	91.8	7	6
	Trentino, Italy	46°N	1932	31.7	70.9	15	11
IV Scandinavia and Baltic States	Hedmark, Norway*	61°N	1934	27.5	88.4	21	21
	Riga, Latvia	57°N	1933	32.8	88.8	10	13
	Flak, Lillesand, Norway	58°N	1933	30.8	87.7	16	16
	Valkjarvi, Finland	62°N	1933	29.7	79.1	18	15
	Vasteras, Sweden	60°N	1934	29.5	89.4	19	14
	Lysekil, Sweden*	58°N	1934	18.5	19.3	22	22
V North German Plain	Potsdam	52°N	1933	34.8	84.4	6	9
	Allenstein, E. Prussia	54°N	1933	34.2	92.7	7	11

Mean of three plots except origins marked *, which are represented only in one plot.

Scots pine

At Thetford Forest, Norfolk, the Scots pine provenance experiment planted in 1932, 1933 and 1934, was assessed early in 1956 at the time of the second thinning. Results are given below. Previous reports on this experiment will be found in the *Annual Report on Forest Research* for 1949 and 1950. Current results are shown in Table 17.

It will be seen that the most vigorous growth continues to be found amongst provenances from the Middle Rhine and Central Germany, and a further provenance from this region (Kassel, Hesse) has in the last seven years overtaken the others. The growth of the provenances from other regions is progressively slower the further north their origin. Analysis of the data shows that there is a significant relationship between latitude and height, which can be expressed by the linear regression Height$=56.65-0.45$ L where L is the number of degrees of latitude North. There is however a slight suggestion from the slower growth of the provenances from farthest south, that this relationship no longer holds for latitudes further south than 48°N.

The slowest provenances, from Lysekil, Sweden is, unfortunately, replicated only once; badly damaged by rabbits in its early years, the plot is very poorly stocked and has scarcely closed canopy. Pine raised from seed of local plantations (East Anglia) maintains its lead over that from native Scottish sources.

POPLARS

By J. JOBLING

Varietal Studies

Varietal Trial Plots 232.12

Planting of trial plots was carried out on a moderately large scale at new sites at Clanna, Forest of Dean, Gloucestershire, Blandford Forest, Dorset, Rogate Forest, Sussex, and at Creran Forest, Argyll. A small number of plots were also laid down at a site started the previous year at Enmore, Quantock Forest, Somerset.

Assessments of height and girth were done in plots planted in 1950 at Quantock Forest, Somerset, and of height, girth and volume of a small number of larger plots planted in 1937 at Yardley Chase, Northamptonshire.

Varietal Collection

The collection of clones showed a net increase of 17, to a total of 333, 28 were added and 11 were discarded. Several selections of *Populus canescens* and *P. tremula* were imported, the best of which will be used in trials and experiments in woodlands. Also added were a number of Balsam hybrids from North America.

Populetum

This now contains 196 clones, an increase of 25 over the previous year. Results have been very satisfactory and most of the trees planted in 1953, the year in which the populetum was started, are now established.

Silvicultural Experiments 232.4

Seven experiments were planted during the winter, bringing the total now maintained and assessed to 44. Two of these are of long-term duration; one being concerned with the growth of poplar at close spacing in coppice, the other with the growth of poplar at wide spacing in mixture with a shade-bearing conifer.

Age and Type of Planting Stock

Two new experiments were planted, at Gaywood Forest, Norfolk and at Creran Forest, Argyll. Both are concerned with comparing the survival and early growth of different ages and types of planting stock, each age/type being represented by a range of sizes of plant.

Previously planted experiments have been satisfactorily informative, and the results of work done during the period 1951-54 are being written up.

Planting Treatments

Two experiments were planted on the sites mentioned above at Gaywood and Creran Forests. They are primarily to compare the effect of different mulch materials on the growth of newly planted stock. The mulches, of conifer bark peelings, cut vegetation, and used fertilizer bags, will be retained for different periods during the establishment stage.

Methods of Planting

Work has continued on the use of explosives for preparing planting pits, the third experiment being laid down during the winter at Gaywood Forest. There are already indications in the first experiment planted at Alice Holt in 1955, that trees benefit by being planted in pits prepared by explosive.

Handling of Plants

No new work has been done on this project. The three experiments planted (1953-55) have so far yielded little information, in that the different exposure and heeling-in treatments applied to the plants have caused no observable differences in their performance after planting. Even plants which had their roots immersed in water for forty days, and others which were completely exposed for forty days, showed the same rate of growth during the first season as plants which were planted out immediately after lifting in the nursery.

Spacing in Plantations

Four experiments, comparing growth at planting spacings of eight, fourteen, eighteen, twenty-six and thirty feet, have been laid down during the past four years. During the winter a canker-resistant clone of *Populus trichocarpa* was planted at close spacings on a cleared coppice site at Alice Holt Forest, to be grown on a short rotation. The main aims of this experiment are to compare the volume production of poplars at different close spacings, and to study the effect of poplar on the regrowth of coppice.

Use of a Forest Tree Species as an Understorey in Poplar Plantations

Three experiments have been planted, the third during the past winter at Gaywood Forest. This will compare the growth of *Populus tacamahaca* × *trichocarpa* 32, with understorey of a shade-bearing conifer (*Thuja plicata*) planted at two different densities, with that of the poplar planted pure.

Nursery Experiments

The Raising of One-Year Rooted Cuttings 232.32

Work continued during the year on methods of raising plantable one-year rooted cuttings. Experiments were carried out at Fenrow Nursery, Rendlesham Forest, Suffolk, and in the poplar nursery at Alice Holt, Hampshire, in which cuttings were inserted at various spacings to determine whether the effect of a wide spacing was beneficial. Due to the poor growing conditions during the summer, however, none of the plants raised reached the required planting standard, and no difference due to spacing could be detected. There are indications from earlier work that little advantage can be obtained in most nurseries by using a wider spacing than normal (fifteen inches between cuttings, eighteen inches between rows), and that usually suitable planting stock can only be raised after stumping and transplanting for one year.

Distribution of Cuttings 232.328

Between January and March cuttings of the standard varieties were disposed of as shown in Table 18.

Table 18

Disposal of Poplar Cuttings: Forest Year 1957

	P. eugenei	*P. gelrica*	*P. laevigiata*	*P. robusta*	*P. berolinensis*	*P. serotina*	*P. tacamahaca* × *trichocarpa* 32	*P. tacamahaca* × *trichocarpa* 37
Forestry Commission	612	400	1,016	24	112	400	926	264
Private Estates	2,035	4,745	730	2,035	300	3,395	1,080	730
Trade Nurseries....	3,450	3,000	100	1,950	100	1,200	200	100
Govt. of Northern Ireland	1,000	2,000	100	500	—	500	100	100
Total	7,097	10,145	1,946	4,509	512	5,495	2,306	1,194

A total of 33,204 cuttings were distributed, as against 23,650 of five varieties the previous year and 32,125 in 1955.

Over 3,000 cuttings of non-standard clones were sent as gifts to research workers abroad, in Canada, Finland, Germany, Holland, Korea, Pakistan, Sweden and Switzerland, as well as to interested growers in this country.

Bacterial Canker Investigations 443

Work of inoculation with bacterial slime of long cuttings was carried out at Fenrow Nursery; 205 varieties, each usually represented by ten cuttings, were planted. In future this project will be centred at a temporary nursery recently established at Gaywood Forest. At all of the major trial plot areas, the planting of trees of highly canker-susceptible clones was continued, these will be inoculated with bacterial slime in the hope that they will contract the disease, and become active sources of canker. It should then be possible over a period to determine the natural resistance or susceptibility of the clones under trial.

FOREST ECOLOGY

By J. M. B. BROWN

Ecology of Corsican pine in Britain 181

The survey of the performance of Corsican pine in Britain, in relation to factors of climate, topography and soil, has been actively pursued during the year.

Particular attention has been given to evidence of the tree's behaviour in areas affected by smoke in South Yorkshire. Atmospheric pollution considerably restricts the choice of species and there is demand for a tree which combines general climatic tolerance on the Pennine uplands with ability to sustain healthy growth in spite of pollution. The limitations to the use of Corsican pine in the Pennines appear to be due rather to general unsuitability of the climate than to ill health caused by industrial smoke, but the evidence is still incomplete.

In a preliminary examination of the relation between site quality of Corsican pine and the temperature factor, yearly average values for accumulated day-degrees above 6°C (42.8°F) have been estimated for all the sites from which growth data have been obtained. A close relationship appears to exist, although certain anomalies require closer scrutiny. The values for accumulated temperature have been estimated without reference to aspect or other local features of topography, which are of considerable importance in hill country. More important is the influence of soil properties towards the climatic limits of the tree, where the general preference for coarse-textured, friable, warm, freely drained soils becomes more pronounced. It may well be that the temperature in the root zone, rather than the air temperature, is of principal significance in differentiating site quality in Britain.

A feature of Corsican pine stands on marginal sites is the susceptibility, usually shown only after the stand has closed canopy, to infection by the fungus *Brunchorstia destruens*, which destroys the young branchlets, as a rule from the tip downwards. Although slow growth and susceptibility to *Brunchorstia* usually go hand in hand, many low-quality upland sites appear to remain unaffected by the fungus, and the particular connection between the two may be incidental. It is too early to suggest what particular feature of the upland climate predisposes to *Brunchorstia* attack, but severe winter cold is under consideration.

Although most of the *Pinus nigra* planted in Britain is derived from Corsican seed, other provenances have entered the country from time to time. Seed origin is examined in all plantations recorded, particularly those on marginal sites. A provenance better suited to upland sites, or more resistant to *Brunchorstia*, than is the *Pinus nigra* from Corsica, would be a useful asset, provided the rate of growth and stem form were satisfactory.

Influence of Forests on Earth Temperatures 114.16

While it has not yet proved practicable to take any systematic measurements of soil temperatures on upland sites where Corsican pine fails or grows very slowly, a series of records maintained for a period of 16 months at Alice Holt indicates the order of the differences in surface soil temperatures between open ground and ground under trees. From February, 1956, until early June, 1957, daily maximum and minimum temperatures were recorded in a modified Stevenson screen, between humus and mineral soil and at 5 cm. depth in the mineral soil on three otherwise homogeneous sites bearing respectively oak, beech and Douglas fir, all 30 to 35 years old. These are being compared with air and soil temperatures on a nearby open site bearing short grass turf. The data may be of interest also in relation to studies of forest litter decomposition, and are being prepared for publication.

Studies of Beech Natural Regeneration 231

An interim report on the Chiltern (Watlington) Forest investigations was prepared in autumn 1956, when a heavy beech mast promised substantial and welcome additions to the existing seedlings which had been under detailed observation since a year after germination in 1951. A rather high percentage of empty nuts and a plague of voles (*Microtus agrestis*) during the winter gravely affected the prospects, and the fresh crop of seedlings will probably fall far short of expectations. The forest floor was roughly cultivated in March, 1957, in preparation for germination, and a thinning, maintaining the thinning gradient established in 1952 and calculated to favour both established and new regeneration, will be carried out late in 1957.

FOREST SOILS

By W. H. HINSON

114

During the year some 250 soil samples for analysis have been received, mostly from the various sections of the Research Branch. The determinations required have been carried out on about three-quarters of this material and work on outstanding samples from the previous year has been completed. A smaller number of samples of conifer needles and ground water has also been analysed for major nutrients in connection with silvicultural investigations.

A complete survey of sources of seedbed cover grit has been carried out, and the results of analysis for lime circulated to the Conservancies. Several cases of the use of unsuitable material were brought to light and corrected.

It seems likely that controlled sand (or water culture) methods should yield information on the nutrition of forest species not obtainable by other techniques. To gain some practical experience in this field a sand culture of poplar (*Populus gelrica*) is being maintained to demonstrate major nutrient deficiency symptoms. The relative growth rates show the over-riding importance of a high level of nitrogen, and suggest that poplar cuttings are unlikely to respond to dressings of phosphorus or potassium except under extreme conditions; a magnesium deficiency characterised by interveinal chlorosis, and in the later stages by a loss of rigidity of the wood, may be readily induced by application of potassium.

Long term studies of the nutrient relation of forest crops and forest sites have been initiated.

FOREST GENETICS 165

By J. D. MATTHEWS and A. F. MITCHELL

The General Programme of Improvement 165.3:232.311

Good progress can be reported in four important projects. The comprehensive Register of Seed Sources for Britain is now taking shape after six years of work and this will be completed in 1960 or 1961. The seed orchard established as recently as 1951 at Newton Nursery (Morayshire) for the production of hybrid larch seed, yielded five pounds of seed in 1956, a yield of just over one pound of seed per acre. The progeny derived from the large-scale crossing programme in this seed orchard are now developing at Alice Holt. The new seed collection net developed in Scotland by Mr. D. T. Seal of the Commission was successfully used to make large-scale controlled crossings on five Plus trees of Douglas fir, which ranged in height from 98 to 131 feet. The planting of comprehensive collections of clones (Tree Banks) representing Plus trees of Scots pine, the larches, Douglas fir and beech was begun at Newton Nursery, Bush Nursery (Midlothian) and Bradon Forest (Wiltshire).

The Survey of Seed Sources 232.311.2

The location of suitable seed sources for current planting programmes continued during the year. The present Register of Seed Sources contains 319 classified entries, totalling 5,506 acres. The results of the Survey of Seed Sources in Scotland were made available to the newly formed Scottish Forest Tree Seed Association.

The study of the natural variation exhibited by European and Japanese larch and Douglas fir was continued.

The Selection of Plus Trees 165.62

The selection and propagation of outstanding phenotypes (Plus trees) was continued. The total number of Plus trees of all species which have been marked and recorded is now 2,072. Five hundred and sixty-four of these are Scots pine.

Vegetative Propagation 232.328

Grafting, the rooting of cuttings and layering were again employed to raise clonal material for inclusion in Tree Banks, Tree Displays and Seed Orchards. The total of grafts attempted during the spring of 1956 was 9,495. The total of successful grafts surviving to the spring of 1957 was 7,754, representing 364 parent trees. The overall success was eighty-one per cent and the figures for the three propagation centres were: Alice Holt 2,533 grafts attempted and seventy-seven per cent success; Grizedale (Lancashire) 4,829 grafts attempted and eighty-five per cent success; Bush Nursery (Midlothian) 2,133 grafts attempted and eighty per cent success.

The propagation of Plus trees of *Thuja plicata*, Norway spruce, Sitka spruce and other species which can be propagated by cuttings was continued. The production of rooted cuttings of X *Cupressocyparis leylandii* was also continued at Alice Holt, Kennington Nursery (Berkshire), Grizedale and Bush Nursery.

The Formation of Tree Banks

The planting of the National Collections of Plus Trees of Scots pine, the larches, Douglas fir and beech was begun in Spring 1957 and a total of 585 clones were planted. The pine tree bank at Newton will eventually consist of 1,500 clones and there is space for 450 larch clones at the Bush site. These and similar tree banks on other sites will be the foundation on which all future breeding work will be based.

Testing the Registered Seed Sources 232.1

Advantage was taken of the good cone crop of 1956 to collect seed from ten registered seed sources of European larch and twelve registered seed sources of

Douglas fir. All these seed sources were located in Scotland and the progeny will be planted on three or four representative sites in Scotland and Northern England so that their vigour, growth, habit and adaptability may be thoroughly tested.

Testing the Plus Trees 232.1

The progeny of sixty Plus trees of Scots pine were planted out on four sites at Kilmory Forest (Argyll), Glenlivet Forest (Banffshire) and Chillingham Forest (Northumberland). The raising of the progeny derived from controlled pollination in the larches, Douglas fir and beech was begun at Alice Holt and Newton Nursery in spring 1957.

Breeding 165.4:232.31

Seed orchards of Scots pine, European larch, Douglas fir and beech are being formed both to produce seed and to provide a means of further improvement of these species. Work is in progress on eleven sites, totalling 120 acres.

Seed orchards composed of clones of European and Japanese larch are being planted to produce seed of the first generation hybrid larch, *Larix eurolepis*. Work is in progress at five sites totalling twenty-eight acres.

Self pollination of the larches and Douglas fir for the production of inbred lines was attempted in spring 1956.

Techniques of Tree Breeding 232.311.3:181.8

The study of methods of rooting cuttings of Scots pine, the larches and Douglas fir continued at Alice Holt, with the object of establishing methods of producing clonal rootstocks for use in seed orchards. Cuttings of Japanese larch, taken in July 1956 from parent trees ranging from eleven to sixteen years of age, were inserted in a sub-irrigated propagation frame equipped with electrical soil warming. Two rooting media were compared in this experiment, and the effects of removing the terminal half-inch, two inches and three inches of the cuttings on the incidence of *Botrytis cinerea* and the rooting of the cuttings were tested. The best combination of treatments was an equal mixture of sand and peat as the rooting medium, and removal of the terminal half-inch of the cuttings. This resulted in the rooting of forty-eight per cent of the cuttings inserted.

Phenological observations were continued during the year. As could be expected from the good summer of 1955, 1956 was a good seed year for the larches and beech, and very good for some other species, notably *Thuja plicata* and Lawson cypress. The somewhat unfavourable conditions during the summer of 1956 did, however, lead to slow ripening of the seed and to an almost complete lack of flowering in the spring of 1957. The early spring of 1957 was mild and many species began to leaf out unusually early. From early April, however, the tempo slowed down and the flushing dates of the beech, oak and ash were almost normal.

A good deal of observational work was done during the spring of 1956 on the flowering of grafts and seedling plants of the larches. This and similar work on the physiology of the flowering of pines, Scots pine and beech is now being done in collaboration with Dr. Wareing and Mr. Longman at Manchester University. Their account of the first year's work appears on page 106 of this Report on Forest Research.

FOREST PATHOLOGY

By J. S. MURRAY

44.48

Work on a variety of tree diseases was continued. A summary of the main lines of research is given below.

Group Dying of Conifers

Further observations on this root disease confirmed the hypothesis that the causal agent is *Rhizina inflata*, which becomes established on recent fire sites from which it attacks adjacent root systems. The symptoms typical of the disease, dead roots, resin exudations from stems and thinning of crowns, have been found on adjacent trees eighteen months after a fire has been lit. Reports indicate that the disease is extending, but is serious mainly in the west and south of Scotland and the English Lake District, though it occurs in other parts of the country.

Top Dying of Norway Spruce

Little further work has been done on this disease apart from routine assessments of marked trees in diseased areas. Further reports were received of top dying apparently following the dry summer of 1955. This supports the general thesis that direct or physiological drought followed by *Rhizosphaera* infection of the needles is the cause.

Resin Bleeding of Douglas fir

Symptoms similar to resin bleeding on Douglas fir have been reported on lodgepole pine from Tentsmuir, Fife, and Kirkhill, Aberdeenshire, Forests. No explanation has as yet been put forward for this phenomenon. Inoculation experiments with a *Cephalosporium* sp., a *Myxosporium* sp., and *Pycnidiella resinae*, the fungi most commonly occurring on diseased stems, have so far proved negative. Work continues on the effect of induced drought on Douglas fir.

Rhabdocline pseudotsugae on Douglas fir

No further reports were received of the occurrence of this fungus on Douglas fir of "Coastal" origin. Assessments of degree of damage on different origins showed that "Coastal" was less seriously affected than "Intermediate" and "Inland" forms. It was observed in one area that *Rhabdocline* was fruiting on two-year-old needles. This is unusual as the life cycle generally occupies one year and juvenile needles are infected. The significance of this observation is as yet unknown.

Keithia thujina on Thuja plicata

An account of current work carried out at Nottingham University is given on page 100 of this report. Spraying experiments to "screen" a variety of fungicides, based on this work, have been made during the autumn of 1956 and the spring of 1957. The object of these sprayings is to try to eliminate over-wintering ascospores which are thought to initiate the first spring and early summer infections. It is intended to follow these up by summer and autumn sprayings to see whether the later infections can be similarly dealt with.

In the isolated nurseries experiment, two further nurseries were found to have become infected in 1956. Now out of the eleven nurseries involved only two are still *Keithia* free. It is not known, however, how the infection came into the nurseries and it may be that some other agency than windblown spores is involved. The general recommendation against transfer of *Thuja* plants from one nursery to another still stands.

The building up of stocks of apparently resistant *Thuja* continues. Observations to date of trial stocks indicate that the plants have a higher degree of resistance than normal but are not completely immune.

Defoliation of Scots pine

Observations were kept up on needle casts on Scots pine, chiefly *Lophodermium pinastri*. Other cases in which *Sclerophoma pithyophila* was involved were found as reported in the previous report. Laboratory work showed that a supposed form of *Pullularia pullulans* occurring in pure culture was a form of *Sclerophoma pithyophila*.

The autumn and winter of 1956 was notable for serious *Lophodermium* attacks on nursery and recently planted stock. Complete defoliation was reported from most parts of the country.

Dieback of Corsican pine

Further cases of dying of Corsican pine at high altitude were seen. This study has now become merged in the general study of Corsican pine now being undertaken by the Ecology section. Specimen material from areas under observations has been examined for fungi, etc.

Meria laricis on larch

Further cases of infection on Japanese larch and Hybrid larch as well as on European larch (the usual host) were found during 1956. Work, which is being carried on at Southampton University, is reported on page 102 of this Report.

Cronartium ribicola

Little further work has been carried out on this disease. As reported in the last issue, a seed orchard has now been established with the vegetative progeny of the *Cronartium*-resistant material received from the United States. The test area at Alice Holt is now well infected and further additions have been made to the pine species under test.

Botrytis cinerea on nursery conifers

Further spraying trials were held. Generally the results were disappointing in that some compounds appeared to achieve a small but not satisfactory degree of control. It is intended to go on with further trials, using a modified technique.

During the work, valuable data has been acquired regarding host susceptibility, etc. Also it has been shown that dense seedbed stocking encourages *Botrytis* attack, so that where losses are common it is recommended that a low stocking density be employed.

Decay and Death due to Fomes annosus

Work on *Fomes* has been broadened in scope, until it is now the biggest project of the section. The butt-rot survey has now been carried out over most of the country, and is expected to be completed in 1957. The aim of this is to classify forests with regard to their need for protection from *Fomes*. As a result of experience derived from the survey, it is hoped that specific recommendations for certain forests may be made shortly. It has been shown also that previous land use in the general area is important in regard to the susceptibility of individual plantations. Thus, areas such as east and north Scotland with a long history of conifer planting are particularly susceptible. This is thought to be related to the availability of air-borne spores in the area. Other important conclusions are coming to light from the survey data and are greatly clarifying the whole general picture of *Fomes* build-up in the country.

A programme of experiments on various aspects of *Fomes* control has also been initiated. Trials of standard stump treatment using creosote have been laid down in different parts of the country, to see whether its effectiveness is altered by changed climatic factors. Also a range of different substances are on trial. Experiments involving different tree and stump treatments have been laid down to test their effect in eradicating *Fomes* from an area and protecting either the standing or the following crop. Trials of delayed thinning treatments have also been started. The development of *Fomes* attack is being checked by natural and artificial stump inoculation in plantations.

In addition work has started on the economic aspect of *Fomes*. To date this has been limited to estimation of decay in one plantation, but it is intended to extend the economic survey to make it fully representative of death and decay in the whole range of coniferous crops.

Bark Disease of Beech

Little further work has been done on this, apart from observations on numbered plots. Several cases of typical symptoms were reported apparantly following the dry summer of 1955.

Sooty Bark Disease of Sycamore—Cryptostroma corticale

No further reports were made of this disease. A survey in 1956 of affected areas showed that the disease was still declining in intensity—a trend which has operated for the past few years.

Elm Disease—Ceratostomella ulmi

Further graftings were carried out using scions of Dutch material sent over to Britain for testing for resistance. Three areas were chosen and planted up with rooted stocks made from previous graftings. Elm trees occurring naturally in the neighbourhood will be inoculated with cultures of *Ceratostomella* to ensure that the disease is present and to provide rigorous conditions for the test plants.

Wound Protectants

Assessment was made of a wound protectant experiment on beech and lime laid down in 1952. Substances used were found to be highly variable in effect. Some had no protective action, some even appeared to encourage decay, while some again had to be ruled out because of handling or application difficulties. Eight of the most promising were used in a second experiment on beech.

FOREST ENTOMOLOGY

By D. BEVAN, J. M. DAVIES and R. M. BROWN

The Pine Looper (Bupalus piniarius)

Pupal Survey 453

The area covered by the 1956/57 pupal survey has been similar to that of the previous years. A few small units have been added, and a total of 42 private and Commission forests sampled.

As might have been expected after a cold wet summer and autumn, there is a fall or little change in populations to report this year. In fact, there are few pinewoods throughout the country with counts of more than one pupa per square yard. Tentsmuir, Fife, is the one exception to the rule where pupal counts gave the following figures:

Pupal counts	*Compts. affected*
70–80	1
60–70	0
50–60	1
40–50	5
30–40	3
20–30	10
10–20	17
below 10	25

It will be appreciated that these counts represent a population well able to cause complete defoliation to those parts of the forest bearing the higher numbers, but it is too early yet to foresee how well this potential will be realized. It is not possible, then, at this stage to forecast what action if any, will be necessary.

Study Plot

Investigations in the 20-acre Study Plot, set up in Cpt. 128 (Corsican pine, 31 years old) at Elveden, Thetford, have now been going on for a full year.

A prime requirement in this attempt to assess the factors influencing population change is the accurate assessment of numbers in all stages, and the expression of them per unit area. From such data it is then possible to calculate successive mortalities, and to draw attention to the critical times in the insects' development. This first year has largely been regarded as a testing period for techniques, though, at the same time, some points of interest have already shown up. Estimates of numbers in all stages have been made as follows:

(a) Pupae were counted in 50 quadrats each of one square yard, distributed in a regular grid over the area.

(b) Adults emerging from pupae in the soil were caught in 50 traps, each of one square yard placed out in a similar grid formation.

(c) Eggs were counted on sample branches taken from all parts of the crown of trees randomly chosen. The number of current year's shoots were also counted. This sampling was continuous with:

(d) In the case of larvae, the branches being taken as in (c), were put into cloth bags, brought down from the crown and the larvae upon them counted.

In dealing with the later instars the bag and branch were placed in a bin and gassed with carbon dioxide, being left there long enough to anaesthetize the insects (which either fall or are easily shaken off the foliage).

In the last stage, a count of larvae dropping from the crown was made by intercepting them on their falling descent to the ground for pupation. 50 trays, each with an area of 1 square yard placed out in a grid, were used for this purpose.

With both eggs and larvae, the numbers found in the sample have to be expressed *per unit area* if they are to be compared with figures for the other stages. In this case, it was done by first finding the girth-class distribution of the trees and using this, together with a correlation between total numbers of current year's shoots and girth of tree. Thus it was possible to translate any sample into terms of the whole crop. The girth-class distribution had been established by girthing every 50th tree, and the correlation between number of shoots and girth by felling 30 random trees, representative of the girth range, counting the number of current year's shoots, and measuring girths.

The correlation coefficient was found to be .795. The regression formula was: No. of shoots $=140 \times$ girth $-1{,}850$, in terms of total shoots per tree and girth in inches.

It will be noted that the number of current year's shoots are taken to represent the amount of foliage on the branch. The method has been used a number of times before, but there is no actual proof that it is a valid hypothesis for conifers, and for this reason it was decided to investigate the question more thoroughly. Branches taken from every whorl of sample trees were stripped of their needles; the needles were weighed and the number of shoots on the sample counted.

A correlation was found between total weights of foliage and number of shoots, having the coefficient .888, and further a correlation between weight of foliage and girth, having the coefficient .861 and regression formula Wt. in Kgms. $=1.30 \times$ Girth -15.3. There was, however, no correlation between numbers of shoots and the weight of foliage vertically between whorls of the same tree. Though the result is the one expected, the variability has emphasized the necessity of either sampling any tree from top to bottom, or, of using a method based on a complete knowledge of this variability. Of particular interest in this investigation has been the apparent, and so far unexplained, disappearance of part of the egg populations during the first and second weeks of August. The drop is significant and suggests that there is actually a true loss of eggs from the trees. This may be important and requires investigation. Again examination of the results of larval counts suggests our technique is far too insensitive to give accurate figures for the first instar. The discrepancy between egg and larval figures should probably be interpreted to mean that, in fact, it is largely due to first and second stage mortality (larvae which we have not at any time succeeded in counting).

The results of the assessment are somewhat difficult to summarize at this stage, but it is felt that there will be interest in the approximate figures below, and in the attendant graphical representation in Figure 1.

Laboratory Studies

Laboratory studies this year aimed to provide an extension to the female pupal weight and fecundity relationship, published in the *Report on Forest Research* for 1956. The previous experiment had used females derived from the complete range of pupal weights found that year in the field, but it did not cover the range possible in this country. It was therefore decided to take advantage of the fact that laboratory-bred individuals tend to be of greater weight than those found outside, and to use these to obtain the information required. The results will be published later.

A further investigation into the number of instars in *Bupalus piniarius* development has brought us very little nearer knowing the normal in nature. By watching the larval history of individuals, four, five, six, and even, in a single case, seven instar developments were recorded. This experiment however was carried out in

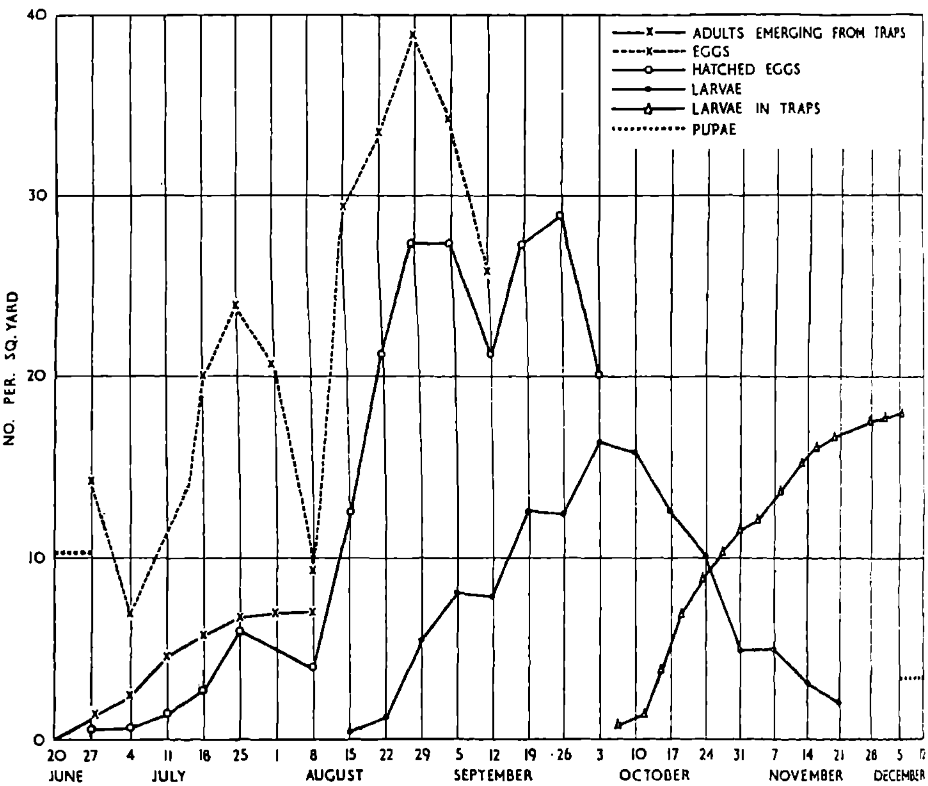


FIG. 1. Assessment of Eggs, Larvae, Pupae, and Adults of *Bupalus piniarius*, in the Elveden Study Plot, 1956. (N.B. Curves for pupae in June and December.)

	Percentage of original population	Percentage mortality between stages
Pupal count, spring 1956=10.2 pupae/sq. yd. (Sex Ratio 49 female: 55 male	—	—
Adult Emergence=7.0 adults per sq. yd. (Sex Ratio 133 females: 218 males, average fecundity at mean weight of .134 gms=130 eggs)	—	—
Total potential egg laying capacity of population=346 per sq. yd.	100%	—
Eggs on reaching a maximum (end of August)=38 per sq. yd.	11%	89%
Larvae on reaching maximum (begin. Sept.)=18 per sq. yd.	5%	53%
Larvae on dropping for pupation=17 per sq. yd.	5%	5%
Pupal count, Spring 1957=3.2 per sq. yd.	1%	82%

the laboratory, in uncontrolled conditions, and it would be wrong therefore to assume that such behaviour can be translated to the forest. We can therefore only state that *Bupalus piniarius* must be added to the list of insects in which variation in the numbers of instars is known. Though the numbers of insects examined were small, and any conclusion must be extremely tentative, there is one interesting result of sexing the pupae from the above experiment. In the 5-instar development, classically taken as typical, the sex ratio is about 1.1; but in the 4-instar, females, and in the 6-instar, males, were rare. The fact that the 4-instar development is actually found in nature is mentioned by Escherich, and was noticed in Britain in 1954. This preponderance of males would undoubtedly have an effect on the next year's population.

Parasites of Bupalus piniarius

Most of the work on parasites till now has been incidental to the host *Bupalus piniarius*. The annual pupal survey has provided the basic material for breeding and recording the various Tachinid and Hymenopterous parasites. At the same time a general picture of the relative importance of certain species was obtained. During the infestation of 1954 three parasites, *Cratichneumon nigritarius* Grav., *Campoplex oxyacanthae* Buie. and *Heteropelma calcator* Wes., in that order, were apparently most numerous. The first attacks the pupa, while the last two are confined to the larval stages.

The present work was started at Elveden, Thetford Chase Forest, in 1956, when more detailed sampling techniques were designed to study the history of *B. piniarius* from egg to pupa in the field. The following account will be based on the data from this source, and additional field and laboratory experiments on the parasites already mentioned.

During the egg stage, *B. piniarius* is attacked by *Trichogramma* sp.; this is a small Chalcid less than 1 mm. long, with a developmental period of approximately 10 days. The larva feeds within the host, and is fully grown in five days. It is at this point that the egg goes black, and may be recognised in the field as parasitised.

The total numbers of parasited and unparasitised eggs were obtained for every ten trees sampled in a week, and throughout the egg laying period of *B. piniarius*. When plotted against time, these two sets of figures, together with the percentage parasitism per week, suggested that the latter might be going up with increased numbers of eggs. The correlation obtained is not high but is positive and significant with a probability of 2 per cent, and does not contradict the reasonable and simple assumption that the parasite has a greater chance of finding its host with increasing host numbers.

Larvae collected from the sample trees were counted and placed in a Kilner jar with fresh foliage. These were bred in the laboratory and the distribution of the parasite throughout the larval instars was studied. The final stage and date of emergence were also recorded. However this proved more difficult than originally supposed, for, of the total larvae collected in the field, 56 per cent died before arriving in the laboratory. The major portion died of starvation as a result of the poor quality food provided, while some deaths were probably due to inevitable manhandling when sampling. These were dissected and no parasites were found. The remaining 44 per cent were bred through, and of these 11.8 per cent were parasitised by *Campoplex oxyacanthae*. This number however, when applied to the field total, would only represent 4.7 per cent parasitism.

Examination of the laboratory observation brought out one interesting feature. There was a suggestion that parasitisation might have an influence on the rate of development of the host larval instars. This will need further investigation in the laboratory.

Fifty pupal plots gave a figure of 1.3 per cent parasitism by *Cratichneumon nigritarius*. Previous work in the field had already indicated that this was a difficult insect to find and study. Consequently emergence traps were designed for their more efficient capture, and laid down in the middle of April. Daily collections were made through May and June, and only a single specimen was caught.

Since the female of this species has a maximum life expectancy of fifty days, this leaves a period of one month to account for till the pupae of *B. piniarius* begin to appear. It would suggest that *C. nigritarius* produces a second generation either on the later hatching pupae of *B. piniarius* from the previous year, or on the pupae of *Panolis flammea* which appear during August. In order to investigate these theories the traps were moved at the end of the flight period of *B. piniarius*, and again daily collections were carried out with the same result as earlier in the season. This same period was covered by a subsidiary experiment, in which five ¼-square-yard plots were laid in a diagonal across the compartment. In each square, twenty laboratory-bred pupae were placed just below the surface layer. They were examined every ten days, and it was found finally that 59 emerged as adult moths, 11 died, 23 disappeared and 7 were partially eaten.

C. nigritarius is known to keep close to the ground during flight, while in the laboratory the female spends much of the time hiding beneath damp moss. This behaviour is obvious in an animal that must search for its host in the litter layers. However unless the parasite is present in vast numbers, or one can sample the ground vegetation with a sweep net every day for two months, other more permanent methods must be used. Hence in September bands of sticky paper were tied round the base of trees, but neither by chance or design was a single specimen caught. In addition nineteen porcelain dishes each containing five fresh pupae were scattered through the compartment, but these also proved unattractive to *C. nigritarius*. Much of this work suggests that this species is not present in sufficient numbers to be studied with any ease in the field. Preliminary work in the laboratory has been confined to the general biology of *Campoplex oxyacanthae* and *Heteropelma calcator*. This should be extended to include more detailed work on larval stage selection, and the parasite influence on rate of host development. In the case of *C. nigritarius* it has been found impossible to breed from the adults that emerge in May. They have never been observed to mate, and studiously ignore the presence of any pupae. A female collected in the field last September was brought back to the laboratory, and placed in a cage with 10 *B. piniarius* pupae. Each day for a fortnight this specimen was observed. The behaviour was the same as with laboratory bred females. She would hide in dark corners, only emerging to feed, and clean antennae, and occasionally stumble over a pupa. At no time was she seen to inspect the pupae, and attempt oviposition. However within five weeks of being placed in the cage, these 10 pupae produced 7 males and 3 female adult *C. nigritarius*.

Fogging Machines

Reference was made in the last annual report to tests of the "Tifa" (Todd Insecticidal Fog Generator) Fogging Machine, and it was then indicated that results have so far been unaccountably poor. A suggestion was then advanced that either the insecticide formulation used or our technique, was at fault in some way. In an attempt to clear the matter up it was therefore decided to accept the very kind invitation offered by Prof. Zwölfer, of the Institut für angewandte Zoologie, Munich, to take part in an actual control operation being carried out against *Panolis grizeovariegata* Goeze, on pine, in Bavaria. Useful experience was gained in the handling of the machine, both from the mechanical and operating points of view, but perhaps the most important lesson learnt is the emphasis to be placed on correct weather conditions. It is essential for successful forest fogging to have an inversion provided by radiation and transpiration cooling the air immediately above the canopy: such a situation will occur only on a still night. Under these conditions the fog is sealed under the canopy, and an average swathe width of 100 yards can be relied on.

In the light of this experience, a further trial was carried out in this country in collaboration with Messrs. Lister Todd (the makers of "Tifa"), and with members of the staffs of Jealots Hill I.C.I. Research Stn. and Plant Protection Ltd. Tests of both standard and a pair of small "Tifas" in tandem, were made in blocks of twenty-two-year-old Scots pine in Bramshill Forest, Hampshire, using 1 lb. of D.D.T. in one gallon of oil per acre. Test insects were again used to assess control obtained and in addition to caged flies hung amongst the branches to gauge "knockdown", a test of residual effect was introduced. Cabbage leaves, which had been placed with the cages, were afterwards fed to larvae of *Plutella maculipennis* Curt.

It will be realised that, for complete success, a trial of the kind, involving as it does the co-ordination of a number of private organisations as well as ourselves, all with limited time on their hands, requires a certain amount of luck with weather conditions. In fact, there was a slight wind prevailing throughout, strong enough at times to upset the inversion and to cause the fog to wander erratically and leak through the canopy. The kill was as expected—good where the fog had behaved itself, but medium to bad where the wind had played tricks with it. *Plutella* mortality roughly followed the pattern of fly knockdown, though the percentage kill of the former was lower.

The "standard" Tifa proved superior to the smaller machine in its present form, although it is understood that the latter is to be modified as a result of this and other trials.

The results are most encouraging, and it is intended to carry out a further trial against a natural population this coming season.

Curculio elephas Gyll.

For the second year in succession this weevil has been imported in large quantities to this country, this time in acorns from Europe. Control measures, using a D.D.T. spray applied to seed beds, gave a good control during last season. Nevertheless, it was found that some had escaped the effects of the treatment, and had overwintered as larvae in the ground. It is not known whether *C. elephas* could develop successfully in this country but, in any case, we obviously do not wish to run the risk of letting it establish itself here. It is therefore intended to introduce inspection and issue of a form of phytosanitary certificate as a requirement of any country wishing to export either acorns or chestnuts to this country.

Trials of Insecticides against the Pine Weevil, Hylobius abietis L.

Work has continued on the five trial areas mentioned in last year's annual report, and a further two have been added, one more in Scotland and one in England. Observations on all seven have now been completed and a full publication of data has been given in a paper to the Seventh British Commonwealth Forestry Conference in 1957.

The insecticides D.D.T. and B.H.C. used alone and together, and dieldrin, were applied as dusts, sprays or dips at various concentrations. All the materials used, regardless of method or concentration, gave an adequate degree of protection from attack by weevils.

Figures of deaths due to attack are as shown in Table 19.

Table 19

Percentages of trees killed by Pine Weevil on Control and on Treated Plots

Site	Death due to weevil attack, per cent			
	1st season		1st and 2nd season	
	Control	Treatments	Control	Treatments
Countesswells A	26.2	0.6—3.9	53.1	1.7— 6.4
Countesswells B	22.3	0.0—4.1	41.3	0.0— 6.2
Buiternach	16.2	0.0—1.4	44.0	0.8—11.1
Pitfichie	38.9	0.0—5.9	71.6	0.0—14.6
Wickerinn	30.6	0.0—0.6	44.9	0.0— 5.8
Ballogie	11.0	negligible	—	—
Hevingham....	18.7	0.0—0.4	—	—

In their second year, plots on three of the sites were retreated with the original materials; though this gave a further reduction in damage, it was generally too small to be of practical importance (particularly when dealing with a declining population as in this case).

Dusts were applied with hand-operated rotary machines, output being calibrated by number of turns of the handle. Spraying was carried out with a pressure-retaining knapsack sprayer, with output calibrated according to time and jet size. Dipping required only a container deep enough to immerse the shoots and stems of the inverted loose bundles of plants (roots were not dipped).

For dusting a circular screen of about 12 inches diameter was held around the plant, the dosage rates being 1 oz. or ½ oz. of dust. An alternative method was also used, in an attempt to speed the operation, whereby the material was applied in a swathe along the line of plants. At a rate of 1 oz. per plant the method proved inferior to the 1 oz. spot treatment, but superior to the ½ oz. spot treatment. Sprays were applied for original treatment, at the rate of 50 cc. per plant and, for the retreatments, to run-off point, thorough wetting of the foliage and stem being achieved. Dipping required the immersion of the bundle of 50 plants as above for 10 seconds, and, after allowing the plants to drip back into the container for a few seconds,they were heeled-in again to dry-off before planting. Plants in all cases were one-plus-one Scots pine transplants.

Dusting proved to be slightly superior to the other methods, but for practical purposes dipping is recommended. D.D.T. mixed with B.H.C. gave slightly superior results than the other materials used. For reasons of cost and convenience, D.D.T. alone is chosen. D.D.T. as a dip at 10 per cent showed slight phytotoxic effects, so a 5 per cent solution is recommended for this treatment, whilst for spraying 1 per cent D.D.T. should be used, applying sufficient to give run-off. If dusting is preferred, one ounce of 10 per cent D.D.T. per plant will prove effective.

It is not possible to state costs precisely, but as a guide, in a user trial at Tentsmuir Forest, for 18 acres of pine, dipping costs with 5 per cent D.D.T. were just below 7/- per thousand plants for materials and labour. Spraying or dusting would probably be in the region of 60/- to 80/- per acre, using hand-operated machines.

Advisory Work

Forty-four private and one hundred and two Forestry Commission enquiries have been dealt with during the year.

REFERENCES

CROOKE, M. *Experiments on the Control of the Pine Weevil,* Hylobius abietis L. Seventh British Commonwealth Forestry Conference 1957.

FOREST MANAGEMENT

By F. C. HUMMEL

61

The Management Section foreshadowed in last year's *Research Report* has now been formed. It has assumed the responsibilities of the former Mensuration Section except for the design and analysis of experiments, a subject which has become the responsibility of a separate Statistics Section. In addition, the Management Section has two new sub-sections, each under a District Officer, dealing respectively with working plans and forest economics. While each sub-section has its special field of work, some of the more important problems are tackled by the section as a whole working as a team. One such task is the assembly and interpretation of some of the facts needed by the Commissioners for reviewing from time to time the felling quota and the question of the national strategic and economic reserve of timber.

Working Plans 62

In the 1956 *Research Report*, an enumeration of the growing stock for a working plan at Inverliever Forest was described; the method was to obtain an objective volume estimate for the forest as a whole, by measuring a limited number of 1/10th-acre circular plots, and to supplement this information with visual estimates of the growing stock in each compartment. This method has now also been tried at Chopwell and Dovey Forests with equally satisfactory results.

Apart from this work on enumeration techniques, a start has been made on evolving suitable methods of soil mapping and on the use of aerial photographs for stock mapping. This work is closely linked with the activities of the departmental Working Plans Committee in which the management section now takes an active part. In order to gain experience in the management problems of a small, very intensively managed woodland estate, a working plan was drawn up for the Bayfordbury Woods belonging to the John Innes Charity, whose co-operation in this matter is gratefully acknowledged.

While the main weight of our current effort is necessarily devoted to the improvement of techniques and to what might be called the "mechanics of planning", the more basic problems of forest management have not been overlooked. Possible methods of improving very abnormal age-class distributions, a subject already mentioned in previous reports, were further examined and are discussed in a paper to be published in *Forestry*. The main outcome of this study is reassuring because it shows that conversion of even very abnormal forests to a condition of sustained yield can be achieved without departing from the currently accepted range of thinning treatments and rotations, and without appreciable sacrifice in volume increment or financial yield. This result paves the way for examining the more complex and related questions:

What is the smallest area for which we should aim at getting a sustained yield, and what area or number of forests should be covered by a single working plan?

Forest Economics 64

The newly-appointed forest economist has been concerned mainly with a broad survey of problems, and of the statistics needed for dealing with them. As the subject of forest economics is virtually co-extensive with forestry itself, the scope of this survey has been wide and has not been confined to the economics of growing timber but has also extended to the economics of conversion and utilization. A start has, however, also been made on a number of specific studies, the most important of which is on the place of hardwoods in the forest economy of Great Britain.

Census of Woodlands 524.6:905

Unspectacular but solid progress has been made with census revision, a total of 250,000 acres of woodland having been surveyed compared with 184,000 acres in the year before. In Scotland, the field survey of the county of Argyll, including the island of Mull, was completed, while in England the county of Warwick was surveyed and a start made on the counties of Cumberland, Essex and Devon.

Apart from a slightly greater use of aerial photographs there were no changes in procedure.

Studies of Growth and Yield 52:56

The revised code of sample plot procedure was reviewed after it had been in operation for a year, and a number of minor modifications were introduced. The number of sample plots established and re-measured during the year is given in Table 20.

Widespread damage was caused to sample plots in Scotland by the recurring gales of the past winter, which culminated in the storm of the 4th February, 1957, when wind speeds in excess of 100 miles per hour were recorded. In addition to the nine plots which had to be written off, many plots have suffered damage in varying degrees and much stem breakage has been reported. Only isolated damage has been reported from plots in England and Wales.

Twenty-five new plots were established in England, none in Scotland, and two in Wales, both in the third series of the high elevation experiment at Beddgelert

Table 20

Sample Plots

	England	Scotland	Wales	Total Great Britain
Plots in being, 31st March 1956	355	227	126	708
Plots established, 1st April 1956 to 31st March 1957	25	—	2	27
Plots written off (Blown, felled, etc.)	—	9	—	9
Plots in being, 31st March 1957	380	218	128	726
Plots re-measured, 1st April 1956 to 31st March 1957	44	95	27	165

at an elevation of between 1,460 and 1,590 feet. Eight of the new plots were established in the forest plots at Bedgebury, and included a plot of *Cryptomeria japonica;* six plots were in spacing experiments and five plots were established in broadleaved species. A sample plot was established in the well-known 96-year-old Douglas fir at Bolderwood in the New Forest. By kind permission of the owner a plot was established in the stand of red oak (*Quercus borealis*) at Herriard Park, Hants. At 51 years the crop has a top height of 73 feet, which is ten feet above that for Quality Class I oak. This stand is believed to be the oldest of its kind in Great Britain.

The provisional yield tables for oak and beech mentioned in the *Report on Forest Research* for 1952 have been revised, the main change being that height at 100 years has now been taken as the criterion for distinguishing Quality Classes instead of height at 50 years; this is because recent re-measurements in our permanent sample plots have shown that in oak and beech little reliance can be placed on a determination of quality class until after 50 years. These tables are about to be published.

The provisional yield table for western hemlock, *Tsuga heterophylla*, mentioned in the 1956 *Research Report* has been published, and a similar table for *Abies grandis* has been prepared. Four quality classes are distinguished. The first quality class with a height of 120 feet at 50 years is 10 feet higher than the first quality class in Sitka spruce and Douglas fir.

No new instruments were tested, but a paper was prepared for *Forestry* on "Plotless enumerations with angle gauges", which reviews the development and application of angle gauges (formerly referred to as relascopes) and the literature on the subject.

Other Work

Among the varied activities that fall under this heading, the following are the more important:—Participation in the second meeting at Geneva of the F.A.O./E.C.E. Working Party on Forest and Forest Products Statistics, a visit to the Soviet Union, lectures and field demonstrations of thinnings and of the tariff method of measurement, despatch of timber to the Forest Products Research Laboratory for testing, and dealing with some 270 enquiries, of which about one-third came from members of the public.

DESIGN AND ANALYSIS OF EXPERIMENTS

By J. N. R. JEFFERS 0 - - 015.5

Since 1946, work on the design and analysis of forest experiments has been undertaken by a sub-section of the Mensuration Section. In September 1956 a Statistician was appointed to the Research Branch and a separate Statistics Section was formed. The duties of this Section are:

(1) to advise all Sections of the Research Branch on the design of their experiments and sample surveys;
(2) to analyse and report on the results of experiments and surveys carried out;
(3) to undertake research into the application of statistical methods of design and analysis to problems of forest research and management.

In addition, a limited amount of advisory work is done for other organisations and research stations interested in forest problems, for example, Colonial Forest Departments, and the Forest Products Research Laboratory.

Reorganisation of statistical work in the Research Station follows the growing recognition of the need for expansion in this work. This expansion involves continuing advice on all aspects of the design of experiments and an improvement in the services offered to other sections in the analysis of their data.

Experimental Design

Designs have been required for a wide variety of experiments ranging from simple nursery experiments to complex progeny trials. While it has been possible to use the simpler types of experimental design for many of the experiments, the special requirements of experiments with long-term perennial crops have made necessary the use of special designs. In particular, the use of covariance and multiple covariance is necessary to account for unavoidable initial differences in experimental material or to extend the experiment over a sufficiently wide range of experimental conditions. The early results from experiments designed as incomplete randomised blocks have confirmed that these designs are of exceptional value for trials of different provenances and progeny. Designs involving fractional replication have, in the past year been used for the first time in the work of the Research Branch. It is too early yet to assess their effectiveness, but these designs have been found to be particularly useful in the early stages of investigations in order to test effects of simple interactions of as many factors as possible. Greater attention has been paid in experiments continuing through the life of forest trees, e.g. progeny trials, to the design of all stages of the investigations to ensure close standardisation of experimental material, that all experiments in a series are comparable, and that subsequent development of the trees can be related to their early performance in the nursery.

Survey Design

There has also been wide variety of sampling problems, including surveys of insect infestations, strength of pitprops, accidents, tannin content of conifer bark, and the stocking and growth of forests. Random and stratified random sampling schemes have in general been used in these surveys, but, in certain cases, systematic sampling has seemed more valuable and a special study has been made of ways of using systematic samples to determine the distribution and occurrence of physical features. Some problems have been met by the use of sequential sampling, and particular economy has been achieved by the use of these methods.

Analysis of Experiments and Surveys

Analyses of some 200 experiments and surveys have been undertaken. In general the usual methods of analysis of variance, covariance and regression have been sufficient but it is becoming evident that the analysis of forest experiments as if they were short-term agricultural crops does not make the best use of the data. In consequence, methods of analysis which describe the continuing growth of the trees as a growth curve have been evolved. A number of these methods have been suggested and trials are being carried out to test the amount of information which results from them.

Analyses of systematic sampling and of multiple regression have been based on matrix methods rather than those which are more generally described in statistical text books, and the possibilities of applying electronic computing to some of the longer analyses of forest experiments are being investigated.

Standardisation of Measurements and Tests of Instruments

The preparation of codes of assessment of forest experiments in various stages of the growth of the trees has continued. The recording of the results of experiment is an important part of experimentation and one which has been much neglected, and this work has therefore been given considerable priority. The Working Party of Section 25 of the International Union of Forest Research Organisations is also studying this problem at the present time, and the Section is co-operating fully with this Working Party. It is hoped that the recommendations of the Working Party will lead to some standardisation of the conventions of measurement in forest experiments.

Growth Curves

The study of growth curves arises from the analysis of perennial experiments which has been mentioned above. In short-term analyses, simple polynomial curves are usually adequate, but, in long-term analyses, more complex curves are necessary, and the relative merits of probit and logit curves have been investigated. Additional interest in the subject of growth curves has been provided by the hypotheses of G. Backmann, and research on the problem is continuing.

Use of Short-Cut Methods

The growing complexity of the methods of analysis used in forest experimentation has led necessarily to these analyses being carried out by a specialised section of the Research Branch. This unfortunately also entails the separation of field officers from their data at the time when they should be in closest contact with it. To remedy this state of affairs investigation into the value of short-cut methods of statistical analyses has been undertaken. Such short-cut methods are not regarded as a substitute for the more usual types of analysis but as an additional aid to them. It is hoped by these methods, to encourage research staff to examine their data by methods which are statistically sound but which do not require the use of calculating machines.

MACHINERY RESEARCH

By R. G. SHAW

0 - - 087

The agricultural engineering industry continues to provide one source of machinery which can, in many cases, be adapted to meet forestry conditions. An instance is the wide range of horticultural machinery which can, with little alteration, be used in forest nurseries.

Several British machines designed specifically for forestry are now available, and it is interesting to note that there are three British-made bark-peeling machines and several makers of power saws. The principal projects covered by the Machinery Research Section during the year were:

Nursery Operations

Two systems of mechanical lining-out are now in limited use, and work is continuing on a machine of American origin designed to line out 6 rows of plants at once. Mechanical inter-row cultivation for the suppression of weed growth is being successfully done, and chemical weed control is being used on an increasing scale. The special low-reduction gearboxes now available for certain tractors giving speeds as low as ⅛ of a mile per hour have greatly improved the prospects of complete nursery mechanisation.

Extraction of Forest Produce

Recent results show no cause for a change in the opinion that one-man power saws for use on conifer thinnings up to 12 in. butt diameter should not weigh more than 25 lb. A design of sledge for hauling timber over the soft peat areas in the Border area has proved successful in reducing the effort required per payload ton.

Tests to discover the pull required to haul timber loaded into wheeled arches in various ways have drawn attention to the advantages of methods used before the days of powerful tractors. Attempts are being made to combine some of these long-forgotten ideas with the advantages of powered traction. A mechanical replacement for the horse is still a very real need for which there is, at present, no complete answer. An investigation into the costs of extraction by three different designs of powered ropeway has shown that, in the thinning stage, they can seldom be worked at an economic rate. The high labour costs involved in their erection and dismantling make them unsuitable for small concentrations of timber. A trial on the extraction of timber by helicopter showed that this can be done very easily, but present costs are five to six times the rate that the operation would bear.

Bark Peeling

Five portable bark-peeling machines have now been tested to find their maximum output rates and their suitability under British conditions, where the tendency is to peel in small concentrations in the forest. Under this method of usage, output rates are overshadowed by the advantages of portability so, for this very mobile work, the smallest machines are the most popular.

Clearance of Derelict Woodland

A long investigation has been carried out into various methods and machines used in the clearance of derelict woodland. An essential difference between clearance of land for forestry and clearance for agriculture is that, in the case of the former, it is not necessary to make a complete clearance. A proportion of the timber can be left standing with advantage, and the vegetation that must be removed can be cut at ground level, leaving the roots in the ground. This means that various forms of cutting blades mounted on the front of tractors in the 60 to 100 H.P. class are, in reafforestation, taking the place of the various tines and grubbers still used in the recovery of ground for agriculture.

For light scrub clearance, there are tractor-mounted and trailed machines which are proving very successful in dealing with stem diameters up to, in some cases, 3 inches. All the machines recently tested in this category have some form of driven knives or beaters which have the advantage of cutting up all the felled vegetation into small pieces which form a mulch. No subsequent raking or burning operations are required.

A number of machines controlled by a man on foot are now on the market and several have been recently tested. These machines all take the same form of a light tubular frame carrying a revolving disc with cutters on a vertical axis. Power to the cutting disc is supplied by a small horse-power engine but, in most cases, the machine is pushed forward by the operator.

Tests have shown that this class of machine is very effective in dealing with small areas of vegetation up to a stem diameter of ½ inch. Everything is chopped up into small particles which are left in a layer on the ground to quickly form a mulch. On larger areas of half an acre or more the usefulness of these machines is limited by the exhaustion of the operator after 1 or 2 hours continuous work.

Drain Cleaning

There is now no shortage of machines designed to clean or dig drains, provided that there is room for a standard tractor to either straddle or work alongside the drain. All these draining machines are carried either on the side or rear of a standard tractor, and they will operate at a rate of 1 to 8 chains per hour, depending upon how much excavation has to be done. No satisfactory answer has yet been found to the problem of cleaning drains in close-standing young plantations. Several drag-line bucket ideas and self-winching machines have been tried, but abandoned owing to the excessive physical effort needed to get them into position. For straightforward drain cutting on open peat there is no problem, as drainage ploughs operate much faster than any of the machines mentioned above.

Liaison

Contact is maintained with the Dominions and the Colonies. Information is passed on request concerning new machines developed either by the Forestry Commission or by commercial firms. Similar contact is maintained with the Food and Agriculture Organisation of the United Nations through representation on working parties dealing with forest machinery.

Instruction

A series of lectures on new and existing mechanical equipment has now been introduced for each course at the forester training schools. These lectures cover the elementary principles of engines and transmissions and instructions in care and maintenance. Some time is devoted to descriptions of new machines likely to come into use in the near future.

UTILISATION DEVELOPMENT

By E. G. RICHARDS

The Use of Home-Grown Timber in Packaging and Materials Handling 834.4

This enquiry, which was started in 1954, was completed during the year. A further 48 firms were visited—mainly in the Midlands, Yorkshire, Tyneside, the West Country and the London area; and 27 replies were received to a postal questionnaire sent to those box and packing case manufacturers in the London area who had not previously been approached.

It was found that about 13 per cent of all the timber used was home-grown. There are few complaints regarding the inherent quality of home-grown timber, and the general impression was obtained that if home-grown softwood were supplied accurately sawn and thoroughly seasoned it could be used on a much greater scale than hitherto, in practically every branch of these trades. A full report has now been published as Forest Record No. 35: *The Use of Home-Grown Timber in Packaging and Materials Handling*, H.M.S.O. 2s. 6d.

Extractives from Wood and Bark 866.4

In collaboration with the British Leather Manufacturers' Research Association, further analyses have been made of conifer barks. In particular more analyses were made of Larch barks. It can now be said that moisture-free Japanese larch bark has on average a tannin content of about 17.2 per cent and European larch bark about 12.3 per cent, both figures being higher than that normally given by oak bark.

Several private firms are now investigating problems concerned with the use on a commercial scale of Sitka spruce bark as a source of tannin.

Analyses were made of Sitka spruce bark which had been obtained by various methods of peeling. Mechanically-peeled bark was found to have a lower tannin content and an undesirably deeper red colour than hand-peeled bark. This deterioration was almost certainly due to the activity of oxidising enzymes which are released when the cell structure is destroyed. To some extent the fall in the tannin content can be prevented by steaming the bark immediately after peeling, but, attempts to control it by treating with enzyme inhibitors have not so far been successful.

A study was made of the rate at which Sitka bark deteriorates when left lying on the forest floor. It was found that if the bark was not removed within about four weeks of peeling the tannin content fell, and the red colour increased in intensity to an undesirable level.

Investigations have also been made into the apparent variation in the tannin content of oak and Sitka spruce bark from standing timber throughout the year. Results so far indicate that winter-harvested bark is somewhat inferior to that obtained at other times of the year.

Use of Timber in Buildings 833

Investigations have continued into the role which home-grown timber might play in the house building industry. Visits have been made to a few building sites to see how the general quality of home-grown timber compares with the quality of the timber—mainly imported—actually in use.

Seasoning in the Forest 847.1

In the winter of 1952/53 an experiment was laid down at Benmore Forest, Argyll and Gwydyr Forest, Caernarvonshire, with the object of assessing the rate of drying of Sitka spruce thinnings when left lying, supported on brash, on the forest floor; the effects of this treatment on the condition of the poles was also studied. Equal numbers of poles of 3, 4 and 5 inch B.H.Q.G. were felled at quarterly intervals until July 1955. Half the poles at each site were peeled immediately on being felled, the other half were left unpeeled.

The experiment ended at Benmore in the summer of 1956 when the poles were extracted from the forest. Tests of compressive strength were carried out on samples cut from the poles, and assessments on the samples were statistically analysed as were the records on rate of drying and condition of the poles. The principal effects observed were the favourable effect of peeling on rate of seasoning, and the faster rate of drying observed with poles felled in the spring and early summer. Strength in compression of props cut from the poles, and incidence of fungal attack, were also influenced to some extent by the experimental variables, especially peeling. The Gwydyr experiment will be completed next year and a full report of the work at both forests published.

Wood Wool 839.1

The investigation into the species, sizes and specifications of timber required for the manufacture of wood wool was completed. It showed that the trade required a fairly close-grained, well-seasoned round softwood timber, preferably whitewood (Norway spruce). For some grades of wood wool, redwood (Scots pine) was acceptable. Other species of softwood grown in this country were either excluded, or accepted only if supplies of Norway spruce or Scots pine were not readily available. By far the greater part of home-produced wood wool is made from imported timber, but most manufacturers said they were willing to accept home-grown timber of the appropriate species, providing their detailed specifications were met in full.

Thinnings House 833

Observations on the two-roomed experimental office building at Santon Downham, referred to in previous reports, continued. The structural and cladding timbers are still giving satisfactory service. A report received from the Building Research Station on the thermal insulation of a cladding panel of the same type as used in the building showed it to be slightly superior to an 11-inch brick cavity wall.

Fencing 831.5

Plans were drawn up this year for trials of round fencing posts of birch and Sitka spruce, some treated with creosote and some with a proprietary water soluble preservative, using the hot and cold open tank technique. Untreated posts of both species will be used as controls. Sites for the trials were kindly provided at farms belonging to the three Scottish Colleges of Agriculture and the Hill Farming Research Organisation. There are nine sites in all, and it is hoped that the results from these different sites will provide information on the value of the treatments under a wide range of soil and climate. Similar trials will be started next year in England and Wales on sites kindly provided by the Ministry of Agriculture, Fisheries and Food.

THE LIBRARY AND PHOTOGRAPHIC COLLECTION

By G. D. KITCHINGMAN

Library 945.14

The number of books in the library on the 31st March, 1957, was 2,851, an increase of 170 during the year. 619 books are now on permanent loan to sectional libraries. Other loans of books numbered 686, while 212 were borrowed from outside libraries. The volumes of periodicals now bound increased from 1,133 to 1,257.

Catalogue

A revision of the library Catalogue of Books and Periodicals, last published in April 1950, is very nearly complete.

Information Files

These files continue to increase: they form a most valuable and carefully indexed collection of typescript reports, reprints, translations and flimsy material generally.

Documentation

Progress is steady but slow. The number of cards in the indices (card catalogues) is now about 74,000, equivalent to about 25,000 references. Lists of references to literature, from home and abroad, on special subjects were supplied to enquirers.

Bibliography of British Forest Literature

Progress continues in this special project. The references selected for inclusion now number over 8,000.

Translation Section

Translation from Swedish, Danish and Norwegian, as well as from French and German, have been regularly undertaken.

We have continued to publish in the Library Quarterly lists of the more important translations which have been completed. The total number now recorded is 82. These translations are available on loan to all members of the Forestry Commission and to any of the centres participating in the International Translation Exchange Scheme of the Commonwealth Forestry Bureau.

We have been building up for some years a dictionary on cards of the more uncommon technical terms. These cards should prove extremely useful as many terms used in forestry and allied subjects, such as soil science, cannot be found even in technical dictionaries, and much time can be wasted in searching one dictionary after another.

We have already 3,730 dictionary cards covering 12 languages.

Photographic Collection

The photographic records section has during the past year been so overwhelmed with requests for slides for illustrating lectures that much of the indexing has remained undone.

The following figures for slides loaned for lecture purposes indicate the extent to which this collection is now being used:

1952/3	652	slides loaned
1953/4	1,216	,, ,,
1954/5	5,081	,, ,,
1955/6	5,458	,, ,,
1956/7	7,740	,, ,,

The photographs in the Official Collection are in as great demand as ever for all the usual purposes.

During the year, the number of colour slides and monochrome prints increased from 3,163 to 3,569, and from 12,365 to 12,764 respectively.

Film distribution amounted to 164 films loaned during the year compared with 105 last year.

The number of photographs and slides added to the general collection is the lowest for some time. The amount of new work being undertaken has been limited severely to allow a depleted staff to meet the requests for copies of existing photographs. In addition the script has been completed and a considerable footage exposed for a film on squirrel control.

PART II

Research undertaken for the Forestry Commission by Workers attached to Universities and other Institutions.

RESEARCHES ON MYCORRHIZA

By Dr. IDA LEVISOHN
Bedford College, University of London

Differential Effects of Mycorrhizal Fungi on Seedling Development 181.351

Synthetic culture experiments have supplied a substantial body of evidence to show that certain mycelia are capable of entering into mycorrhizal partnership with certain tree species. There is also much information available as regards the almost regular occurrence of certain sporophores in the neighbourhood of certain tree species. However, very little is known about the physiological specialisation of mycorrhizal mycelia in relationship to tree growth, a phenomenon which should be of interest to practical forestry.

(1.) Effects of a Given Mycelium in Different Soil Environments

Results of field experiments carried out during the last years have indicated that unequal effects of mycorrhizal fungi on seedling development are frequently associated with the ecological conditions under which the plants are growing. Differential effects produced by a certain mycorrhiza-former on a given tree species growing in two different soils have already been mentioned in the *Report on Forest Research*, 1956. It was recorded that *Boletus scaber*, observed to stimulate birch seedlings in soil from the Wareham area, had failed to produce any effect on one-year-old birch growing in soil from Wykeham Moor, Yorkshire. At the time, it was assumed that *B. scaber* was already present in the Yorkshire soil, and that the extra inoculum had therefore been ineffective.

During their second year of growth in the Wykeham Moor soil, the performance of the inoculated seedlings changed unexpectedly. Both composted and uncomposted series of pot-cultures showed a pronounced retardation in development as compared with the uninoculated plants. At the end of 1956, assessment of the two-year-old birches in the soil from Wykeham Moor gave the following figures for average height:

(a) Control series not inoculated with *B. scaber* (24 plants) 18.3 inches
(b) Series inoculated with *B. scaber* (23 plants) .... 11.3 inches

The leaves in the inoculated series were markedly smaller than those of the uninoculated plants. Discoloration induced by the inoculum was noticeable.

So far, no satisfactory theory can be put forward to explain the effect produced by *B. scaber* on the young birches growing in this particular soil from Wykeham Moor. (The strain of *B. scaber* applied in the experiments was isolated from a sporophore collected at Wareham; an isolate from a Wykeham Moor sporophore has not yet been used).

There is reason to believe that *Boletus carpini*, and not *B. scaber*, may possibly be responsible for the formation of mycorrhizas and the relatively fair development of birch in the soil from Wykeham Moor, since *B. carpini*, a species very similar to *B. scaber*, has been observed to occur under birch growing in the area from which the experimental soil was transported. It is suggested tentatively that *B. scaber*, which has been suspected for some time to suppress mycorrhiza-formation of certain mycelia, might also inhibit the activity of *B. carpini*. Studies concerned with possible antagonistic effects of *B. scaber* against a number of selected fungi are in progress.

(2.) Effects of Different Mycelia in the Same Soil Environment

Unequal effects produced by two mycorrhizal mycelia on the development of seedlings growing in the same soil, were demonstrated in an experiment carried out in pits (for description of pits cf. *Report on Forest Research* 1956). One of the pits containing soil from Wareham was inoculated with sporophores of *Boletus scaber*, the other received sporophores of *Amanita muscaria*. In the spring following inoculation, one half of each pit was sown with birch, the other with Norway spruce. It was soon obvious that birch and spruce seedlings benefited from the introduction into the soil of *B. scaber* (Plate 3, upper picture) while hardly any effect from inoculation with *A. muscaria* was noticeable (Plate 3, lower picture).

Root examination carried out on two-year-old seedlings showed the following conditions:— In the pit inoculated with *B. scaber*, birch was fully mycorrhizal. Norway spruce was equipped with a large proportion of normal mycorrhizas and a small amount of pseudomycorrhizal infection. In the pit inoculated with *A. muscaria*, birch showed some few mycorrhizal associations. Norway spruce had traces of mycorrhizal infection and a large number of pseudomycorrhizas.

Differential effects from inoculation with mycelium of *Boletus bovinus* and *Boletus scaber* were recorded in sand-cultures with Scots pine seedlings as test plants. The average height of one-year seedlings, 60 plants in each treatment, was as follows:

(a) Series inoculated with *B. bovinus* 2.9 inches

(b) Series inoculated with *B. scaber* .... 1.9 inches

Control cultures without fungus inoculation were on the level of the (b) series.

In the (a) series, the root systems, showing dichotomous branching, were mycorrhizal. The (b) series had not produced any regular forking of the roots and was non-mycorrhizal.

The result of this experiment, which demonstrates that *B. scaber* does not stimulate Scots pine seedlings growing in sand, is in line with observations on pot-experiments with soil from various parts of the Wareham area in which Scots pine, in contrast to birch and other tree species, did not benefit from inoculation with *B. scaber*. Experiments to test the effect of *B. scaber* on pines growing in soils other than those from Wareham have not been carried out.

Antagonistic Effects of a Common Soil Fungus on Mycorrhizal Mycelia

Alternaria tenuis is a *fungus imperfectus* of wide and common occurrence in soils of various types. It would appear that its presence is particularly prominent in cultivated soils. The mycelium can be isolated without difficulty, and grows on a wide range of culture media. On several occasions, *A. tenuis* has been isolated from the soil of nurseries at Kennington and Ringwood (J. H. Warcup includes *A. tenuis* in the list recording the fungal species which he isolated from the Old Ampthill Nursery, Bedfordshire).

In mixed cultures on a synthetic medium, the isolates from Ringwood and Kennington were observed to inhibit the growth of several ectrophic mycorrhiza-formers tested i.e. *Boletus granulatus*, *B. variegatus*, *B. bovinus*, *B. scaber* and *Rhizopogon luteolus*. Pseudomycorrhiza-formers like *Mycelium radicis atrovirens* and *Rhizoctonia* were not effected by *A. tenuis*.

So far there is no experimental evidence that the reactions of the root-fungi to *A. tenuis* in a soil medium are similar to those observed in mixed culture. However, experiments have now been started to test the fungistatic properties of *A. tenuis* under natural soil conditions. Since most of the ectotrophic mycorrhiza-forming mycelia fail to grow in some of the soils from Kennington, Ringwood, and nurseries of similar type, one feels tempted to see a possible relationship between the fungistatic action of *A. tenuis*, the absence of mycorrhiza-formation in the ectotrophic tree species, and their poor growth in the above-mentioned nursery soils.

Induction of Forking in the Roots of Young Pines

Last year's researches were largely concerned with the study of root branching in actively growing pine seedlings (cf. *Research Report*, 1952). Results of experiments in water-cultures demonstrated differences in the morphological structure of what is generally referred to as forked or dichotomously branched short roots, dependent on the nature of the substances introduced into these cultures. It was, *inter alia*, observed that several mycorrhizal fungi induced a kind of branching different from that produced by certain growth substances like beta-indole-acetic acid and tryptophane. It has, however, yet to be tested whether the amounts of the active "factors" and not their nature might determine the different kinds of root-branching referred to.

Among a large number of common soil fungi tested, none were observed to be able, under the experimental conditions, to give rise to branching of the roots.

The studies which were carried out in water-cultures have now been extended to soil cultures in which growth-substances are tested as regards their influence on root forking (and plant development).

Influence of Mulching on Tree Growth and Root Infection

For a number of years mulching experiments have been carried out in various parts of the Wareham area with the following objects: (1.) to assess the effects of a mulch cover on the development of certain tree species; (2.) to study the behaviour of mycorrhizal and other root mycelia under the new ecological conditions provided by the mulch; (3.) to enquire into the role which these fungi might play in the mulching effect on the higher plant. In previous communications (*Reports on Forest Research*, 1951, 1954) it was reported that, following the application of a mulch cover, drastic changes had invariably been observed to accompany the improvement in growth and health of Sitka spruce, Norway spruce, birch, Lawson cypress and alder buckthorn. These observations have since been confirmed and additional data have been supplied by the old experiments, some of which are closed now, and by various new experiments.

*Expt. W.*87 *P.*48: (mentioned in *Report on Forest Research*, 1951). A randomised planting experiment with Norway spruce, brought to an end in 1956. The trees, slightly parasitised when planted, were submitted to the following treatments in the field:

(1.) Control (0)
(2.) Inoculated *Amanita muscaria* (I)
(3.) Added $\frac{1}{8}$ of the standard amount of compost (C/8)
(4.) Added full amount of compost (C)
(5.) (2) + (3) (C/8 I)
(6.) (2) + (4) (CI)
(7), (8), (9), (10), (11), (12), combinations of the 6 treatments with bracken mulching; i.e. (MO), (MI), (M C/8), (M C/8 I), (MC), (MCI).

There were nine plants in each of the 12 factorial treatments, replicated in 4 blocks; in all, 432 plants.

Towards the end of 1955, the experimental trees, which had suffered severe set backs, showed a good survival in the mulched plots. Among the unmulched trees only very few and very chlorotic plants, in condition of pronounced check, survived. When the experiment was closed, the death-rate recorded was as follows:

Control, no mulch (1) and (2)	84.7%
Slightly composted no mulch (3) and (5)	38.9%
Fully composted, no mulch (4) and (6)	21.7%
Mulched control (7) and (8)	13.9%
Mulched, slightly composted (9) and (10)	6.9%
Mulched, fully composted (11) and (12)	6.7%

All mulched plants showed good colour of foliage. The stimulating effect of the mulch treatment on height was in the following order, combination of mulching with full composting and fungus inoculation being the most beneficial: (MCI), (MC), (M C/8), (M C/8 I), (MI), and (MO). The average height was: Control (unmulched)—6.3 in.; control + mulched—15.4 in.; mulch + compost + inoculation—28.5 in.

Among the unmulched survivors, plants in the plots which had received fungus inoculation exhibited, without exception, a better colour than the trees which had not been inoculated.

As regards the root infection of the experimental plants, none of the surviving trees, at the close of the experiment, showed any trace of the pseudomycorrhizal association observed to be present when the trees were planted, and still recorded for the unmulched plants up to 1954. In 1956, the very chlorotic trees among the unmulched plants showed some slight traces of mycorrhizal infection, while the less chlorotic specimens were equipped with a fair number of mycorrhizal associations. All mulched plants were fully mycorrhizal.

The mycorrhizas observed to be present in the experimental trees were all of the same type, apparently formed by *Boletus bovinus*. There was no indication that *Amanita muscaria* had produced any associations in the inoculated plots. The improvement in colour and the casual stimulus to growth following the introduction of *A. muscaria* may be due either to a rhizosphere activity of the mycelium or to the extra addition of nutrients provided by the sporophore material which was used for inoculation. (Unfortunately, there were no comparable controls with addition of sterilized sporophores of *A. muscaria*, or with a different fungal species.)

Expt. W.99 P.51: Designed to assess the effects of heather mulching, potash application, and clean screefing on tree growth and root infection. This experiment was superimposed on the old Expt. W.54 P.40-41, in which the trees, imported from Kennington nursery, had remained in check, showing stunted growth and yellowish colour of foliage. The plants spaced along furrows, were treated in June 1951 in 4 replicated units of 6 plants each, with a considerable buffer between the treatments.

From the next spring onwards it was observed that the mulch produced a markedly beneficial effect on colour and growth of the plants. The potash treated units (in strong *Calluna* growth) behaved similarly to the controls, i.e. they kept their unhealthy colour and made very little growth. In the screefed plots, colour and growth of the trees improved steadily, but the plants are still far behind the mulched trees.

Table 21

Average height of Lawson cypress on Plots Receiving Various Treatments

Heights in inches

Date of Assessment	Treatments			
	A Control	B Potash	C Mulch	D Screefing
28. 5.52	20.1	19.8	21.0	*
9. 3.53	21.3	20.9	23.0	19.4
20.10.55	22.3	21.9	32.2	23.7
2. 3.57	**21.5	22.2	35.9	26.9

*Screefing was only started in June 1952.
**Die-back of two controls accounts for lower average.

The average increase in growth, at the close of the experiment, was therefore as follows: Control—1.4 in.; potash—2.4 in.; mulching—14.9 in.; screefing (carried out one year later than the other treatments)—7.4 in.

At the start of the experiment (29.6.51), root examination did not reveal the presence of infection in any of the treatments. However, during the winter months of the same year, and of the following years, infections by the pseudomycorrhiza-former *Mycelium radicis-atrovirens* were observed in all unmulched plants, particularly in the controls and the potash treated trees.

M. r. atrovirens formed large crusty sclerotia within the outer cortical cell-layer of the roots, obviously blocking the cells. The infection was mainly seasonal, it occurred only very casually during the summer.

As early as the end of 1951, the mulched plants showed traces of endotrophic mycorrhizal infection and were deeply mycorrhizal throughout the following years. Neither the controls nor the potash-treated plants have so far been observed to have normal mycorrhizas at any time of the year. The plants from the screefed units have shown mild attacks by *M. r. atrovirens*, and a small proportion of mycorrhizal infection.

The results of the two foregoing field experiments, together with those of other trials, may be summarised as follows:

On acid soils, mulching of checked trees produces beneficial effects on tree development, associated with changes in quantity or (and) quality of certain common root infections: These changes may involve:—

(1) Increase in mycorrhizal infection when initially present in the plants, or induction of mycorrhizal associations by mycelia present in the mulched soil.
(2) Disappearance of pseudomycorrhizal infection with replacement by mycorrhizas.
(3) Development of heavy investment by mycorrhizal mycelia around the roots.

From these experiments, which demonstrate the apparently simultaneous effect of mulch cover on tree growth and mycorrhizal activity, no conclusion can be drawn as to whether the stimulation of mycorrhizal activity recorded during the mulching period is, at least in part, responsible for the improvement of the higher plant. It might as well be argued that the change in root infection is not a cause, but the result of the better tree growth.

Pot-cultures

In a further attempt to analyse the role of mycorrhizal mycelia in the mulching effect on the higher plant, pot-culture experiments with sterilized and not sterilized soil were set up, half of each series being inoculated with *Boletus scaber*, and half not inoculated. *Pinus radiata*, birch, Norway spruce, and Lawson cypress were used in these experiments, in which pot-cultures of one-year seedlings were plunged in gravel pits covered, *in toto*, with a heather mulch on April 6th, 1956. During the course of the experiment, mulched and unmulched pots, 140 in all, were watered regularly.

By the beginning of May, all unmulched seedlings of *P. radiata* were dead, while the mulched pines had survived. Birch, Norway spruce, and Lawson cypress showed marked improvement in colour of the foliage. After six months from the start of the experiment, the mulched plants in sterilized and not sterilized cultures, with and without inoculation, were recorded to be much superior in height and colour to the unmulched plants. The mulching effect was as drastic in the sterilized as in the unsterilized series. Root examination of the trees from the "mycorrhizal" soils failed to reveal a reaction of the mycorrhizal mycelia, originally present in the soil or inoculated into the soil, to the mulch cover.

The results of this experiment did not give any indication that the mycorrhizal mycelia played a primary role in the mulching effect on the higher plant; i.e. that stimulation of their activity preceded stimulation of tree development.

One seems justified to assume that, in this particular pot-culture experiment, the strong protection against low temperatures was of prominent importance in the effect of the heather mulch likewise observed on cultures in sterilized and unsterilized soil. It happened (fortunately for the sake of the experiment!) that night frosts were rather severe when mulching was started. The average minimum temperatures for the period of mulching between April 6th and May 1st were:—air-temp. 37°F, ground temp.—29°F; those for the period between May 1st and 22nd were:—air temp.—46°F, ground temp.—35°F. At these low temperatures, the mulch cover was, apparently, essential for keeping alive the seedlings of *Pinus radiata*.

STUDIES IN SOIL MYCOLOGY

By Dr. C. G. DOBBS and Dr. JOAN BYWATER
Forest Botany Section, University College of North Wales, Bangor

Mycostasis in Soils 181.351

With the assistance of a Forestry Commission grant, research on this subject was taken up by Dr. Joan Bywater in January, 1957, the aim being to elucidate further the phenomenon of the inhibition of germination of fungal spores and of growth of hyphae in soils, to which attention has been drawn by previous work in the Section. This recently discovered but little understood phenomenon has a probable bearing on several forestry problems—for instance, those connected with the "toxicity" of certain soils notably at Wareham Heath, soil sickness in nurseries, the effects of partial sterilisation, and the effects of soils on the growth of root-infecting fungi, both symbiotic and pathogenic.

Studies directed towards discovering how and under what conditions fungi exist and grow in forest soils have been in progress at Bangor since 1947, and two present members of the Research Branch contributed to their development before joining the Forestry Commission. Mr G. D. Holmes (1947-48) made a promising start in an ecological study of fungi growing on, or isolated from, surfaces of glass and cellophane buried in soil. To Dr. W. H. Hinson (1950-54) however, belongs the credit for devising a technique which has demonstrated the almost universal character of a phenomenon which had been noted in passing in special instances by several mycologists.

Background of the Current Work

Since Dr. Hinson's work forms the main background of that now being pursued at Bangor, a brief outline is necessary as an introduction.

Mycelia growing on protected surfaces of glass slides buried in soils under Norway and Sitka spruce and under beech, were found to originate mainly from spores germinating in condensed water on the glass, and not in general, as had previously been supposed, from mycelia growing at large in the soil. This observation has some importance in view of the widespread use of buried glass slides and tubes for studying soil fungi.

The failure of spores, capable of germinating in distilled water, to germinate in the soil solution, must be attributed to the presence, in nearly all surface soils so far examined, of a diffusable inhibitor. This was demonstrated by the use of thin cellulose film, autoclaved in water to remove the dressing, smeared with the test spores on one side, and placed in close contact with a moist soil surface on the other. The test took two main forms, the "closed" fold, in which the film is folded with the spores inside and pressed between two lumps of soil; and the "open" fold, in which the film is carefully opened without disturbing the contact on one side, so that the spores are fully exposed to the air. In the "closed" form conditions of aeration are such that, with a kaolin or deep subsoil control, germination is reduced to about 5 per cent; in the "open" form it is about 95 per cent; but with both tests Hinson found no exception to the total inhibition of the germination of the spores of *Penicillium frequentans* on the soil contact area of the film, provided that due precautions were taken to ensure perfect contact and no condensation on the surface.

Soils so tested included a range of forest soils, under beech, oak, sycamore, Norway and Sitka spruce, Douglas fir and Scots pine, 6 waterlogged soils, 5 grassland, 3 garden soils and John Innes compost. Shallow soils a foot or so deep showed the inhibition at every level down to the parent rock, but in deep soils it decreased with depth, and was found to be absent in some subsoils at about 6 feet, and also from deep mineral material from an open-cast coal working. So far as can be judged the effect appears broadly to co-exist with biological activity in the soil.

The species inhibited included a mixed inoculum of mould spores from a soil plate, and a wide range of common soil moulds. So far, no fungus tested, of which the spores germinate freely in distilled water, has been found to be unaffected. The growth of germ tubes, also, was found to be halted by the inhibitor. *Penicillium frequentans* was selected by Hinson as a test fungus owing to its sensitiveness to the effect.

Germination, however, occurs when dilute glucose solution is added to the soil at a concentration above a "threshold value" which was found to vary widely in two different soils. The soil so treated recovers the power to inhibit spore germination after some days, corresponding to the time taken for the soil organisms present to attenuate the added glucose. The addition of mineral nutrient and of asparagine to the soil does not have a similar effect. Autoclaving, desiccation, prolonged storage—any treatment liable to release nutrient by killing organisms in the soil—also removed the inhibition, whereupon the soil may support a growth of sporulating moulds. Heating to 60°C, treatment with organic solvents (ether, acetone, propylene oxide) and addition of activated charcoal to the soil all were found to remove the inhibition, which was restored spontaneously in a few days after the heat treatment, and after evaporation of the solvent. Seitz-filtered water extracts of one garden soil were found to produce a significant reduction in the percentage germination of the test spores, but the activity of the extract fell off with storage. There were indications also that the spores are more sensitive to the inhibitor under conditions of poor aeration.

Work in Progress

Among the many lines of research arising from this work which could be followed up with advantage, it is hoped to pursue the following three:

(I.) To find some means of assaying and comparing soils in respect of the inhibitor and of ability to support mould growth.

A start has been made on this by Dr. Bywater. Certain anomalies in the behaviour of *Penicillium frequentans* spores over water have led to the adoption of *Mucor ramannianus* as the chief test organism. This, while usually giving no germination with the "closed" fold, shows a range of germination percentages with the "open" film. As a result, three levels of mycostasis in soils can now be distinguished by the cellulose film test:

(1) Soils which completely inhibit germination both on the "closed" and the "open" film.
(2) Those which inhibit completely on the "closed", but allow some germination on the "open" film.
(3) Those which allow germination on both the "closed" and the "open" film.

Except for deep subsoils, the last category is limited at present to two samples of dark forest humus collected under pine and oak respectively in February, 1957.

These, when merely incubated at 27°C, grew moulds profusely; but mould growth on incubation has occasionally been observed also on the surface of soils which inhibit germination. The two forest humus layers mentioned above, when tested again in April, showed some patchy inhibitory effect. A monthly test is now being applied to these, and to a few other soils with a view to discovering whether variations in the inhibitory factor are seasonal. Less frequent tests are being applied to a wide range of soils for purposes of comparison. The "glucose threshold" is also being studied in conjunction with the ordinary inhibition test.

(II.) To extend the range of fungi tested for susceptibility to soil inhibition, and especially to apply suitable tests to the spores and mycelia of basidiomycetes.

Preliminary work by Dr. Dobbs in 1955 has shown that the mycelium of *Polystictus versicolor* in agar culture is affected by an inhibitory factor diffusing through cellulose film from fresh soil. More recently, Dr. Bywater has studied the effect of the inhibitor on macerated mycelia of a range of basidiomycetes. In general there appears to be an inhibition or reduction of growth, but the results are not at present conclusive owing to many complicating factors concerned with the availability and distribution of nutrient, and the ability of most basidiomycetes to attack cellulose. The conidia of *Fomes annosus* and of *Collybia velutipes* have been shown to be inhibited from germination in the "closed" fold.

(III.) To elucidate further the nature of the inhibitory factor or factors concerned and if possible to isolate and identify the substances and organisms (if any) responsible.

This may well be a long-term task as it is by no means certain that a single factor is being studied in all the soils. In the case of samples of marine sands from Newborough Warren, Anglesey, it seems clear that a chemical inhibitor which survives washing and autoclaving is present, in addition to another which is removed by autoclaving. Secondary effects due to the growth of organisms during incubation of the soil may also complicate the situation, especially where glucose is added. Under these circumstances some soils swell and give a reasty odour owing to a multiplication of yeasts and bacteria within them. Several indications, including the germination of spores and the growth of moulds on the exposed surface of soils which inhibit with the film tests, suggest the possibility that a volatile inhibitor may be present.

STUDIES IN LITTER DECOMPOSITION

By Dr. W. R. C. HANDLEY
Imperial Forestry Institute, Oxford

114.351

Investigations into the nature of raw humus showed that in the leaves of some plant species there are substances, of unknown identity at present, which are able to form stable complexes with proteins. It is considered that these substances unite with residual leaf proteins, when the leaf dies, resulting in complexes which, in the case of plant species associated with the formation of raw humus, are especially resistant to decomposition by micro-organisms. This will result in much of the litter nitrogen being unavailable for use in further plant growth for a more or less long period of time. Other plant nutrients, such as phosphorus and calcium, may also be rendered unavailable at the same time. It is perhaps significant that forest trees planted on raw humus sites often show more marked responses to nitrogenous fertilizers than to other fertilizers, even though the raw humus may contain considerable quantities of nitrogen.

It is therefore of importance to know the nature of the substances in leaves which unite with residual leaf proteins when the leaf dies, as a preliminary to more detailed study of the systems concerned in the breakdown of protein complexes in litter, and the influence of environmental and other factors on such systems.

Such information could be of considerable importance in relation to the growth of those tree species, which include many of economic importance, associated with the formation of raw humus on certain sites, especially in relation to the need for the presence of other species and the application of inorganic fertilizers.

The presence of substances able to unite with proteins is not restricted to the leaves of species associated with the formation of raw humus. There are indications, however, that the substances themselves, and the properties of the protein complexes they form, especially resistance to decomposition by micro-organisms, vary according to whether a species is able to give rise to raw humus or not.

A comparative study of these protein-precipitating substances in the leaves of a range of plant species has therefore been undertaken by Dr. H. Raudnitz.

In preliminary work on the development of methods for the isolation of these substances, the leaves of *Rhododendron ponticum* have been used, since the litter of this species is associated with pronounced raw humus formation on base-deficient soils; in addition the leaves contain relatively large amounts of protein-precipitating material, are readily available throughout the year, and are easy to handle.

The protein-precipitating substances are readily soluble in water at room temperature. Aqueous extracts have therefore been made of fresh leaves, and of fresh leaves rapidly dried at a temperature not much above that of room temperature.

The protein-precipitating substances, along with other materials, can be removed from the aqueous extracts in the form of water-insoluble lead salts. The lead salts have been decomposed, and the resulting mixture of substances subjected to various procedures, including extraction with a variety of organic solvents, in order to separate the various constituents.

Of the materials so far isolated in a pure state and identified, none have the property of precipitating proteins.

Efforts to isolate and characterize the protein-precipitating materials are continuing.

(An account of the earlier investigations has been published as Forestry Commission Bulletin No. 23, *Mull and Mor Formation in Relation to Forest Soils*, H.M.S.O. 10s.)

EFFECTS OF TREE GROWTH ON THE SOIL

By Dr. T. W. WRIGHT
The Macaulay Institute for Soil Research, Aberdeen

Tree Growth on Sand Dunes 181.343:114.3

In 1956, the third season after treatment, young Corsican pine at Culbin Forest showed a significant response in height growth to the application of ground mineral phosphate in 1954. The effect was small (1.4 inches $\pm$ 0.52 inches), and was not accompanied by any significant change in the major nutrient content of the needles. It may be concluded that phosphate manuring does not have the same important effect on tree growth on sands as it does on peat and upland heath soils, but the assessments are being continued to see how long the improvement lasts.

Chemical analysis of needles collected at the end of the first growing season from plots treated with nitrogen, potash and magnesium fertilizers in 1956 (*Report on Forest Research* 1956, p. 81) showed that on a dry weight basis the added nitrogen had increased the nitrogen content of the needles by about 50 per cent, and had decreased the levels of phosphorus, potassium, calcium, and magnesium, although these decreases were only a "diluting" effect due to the increase in dry weight of needles in plots receiving nitrogen. The potash fertilizer had increased the uptake of potassium, and decreased the uptake of magnesium, without affecting needle dry weights, and the addition of magnesium fertilizer had as yet had no measurable effect. No treatment produced any increase in height growth this first season.

In collaboration with Mr. G. M. Will, New Zealand Forest Service, a study has been made of the total content of major nutrients of individual Scots and Corsican pines of different ages growing at Culbin, in order to obtain more information on the amounts of these elements immobilized in the growing stock and removed in utilization (a paper on this topic has been accepted for publication in *Forestry*). Of the variations observed between different parts of the tree, the most pronounced were those between the heartwood and sapwood of the main stem. The phosphorus and potassium contents of the heartwood of both species were very low, but calcium, magnesium, and sodium tended to accumulate. In the sapwood zone immediately surrounding the heartwood, high levels of all major nutrients were found. These differences were particularly marked in Scots pine, whose heartwood formation is greater than Corsican. The bark and stem were shown to contain between one-half and one-third of the total nutrients in the tree, depending on age. Barking of stems in the forest would reduce nutrient losses from the site, but appreciable quantities are still removed in the wood.

Tree Growth on Deep Peat

During the year, work carried out by Mr. W. O. Binns at the Lon Mor, Inchnacardoch Forest, on the physical and chemical changes taking place in deep peat as a result of afforestation, has been concentrated on an experimental plot of lodgepole pine planted in 1928, part of which was manured with ground mineral phosphate in 1939 (Experiment 47). Analyses of peat samples at depths down to two feet (or to the underlying rock where the peat is shallower) show that amounts of all major nutrients, particularly of potassium and inorganic

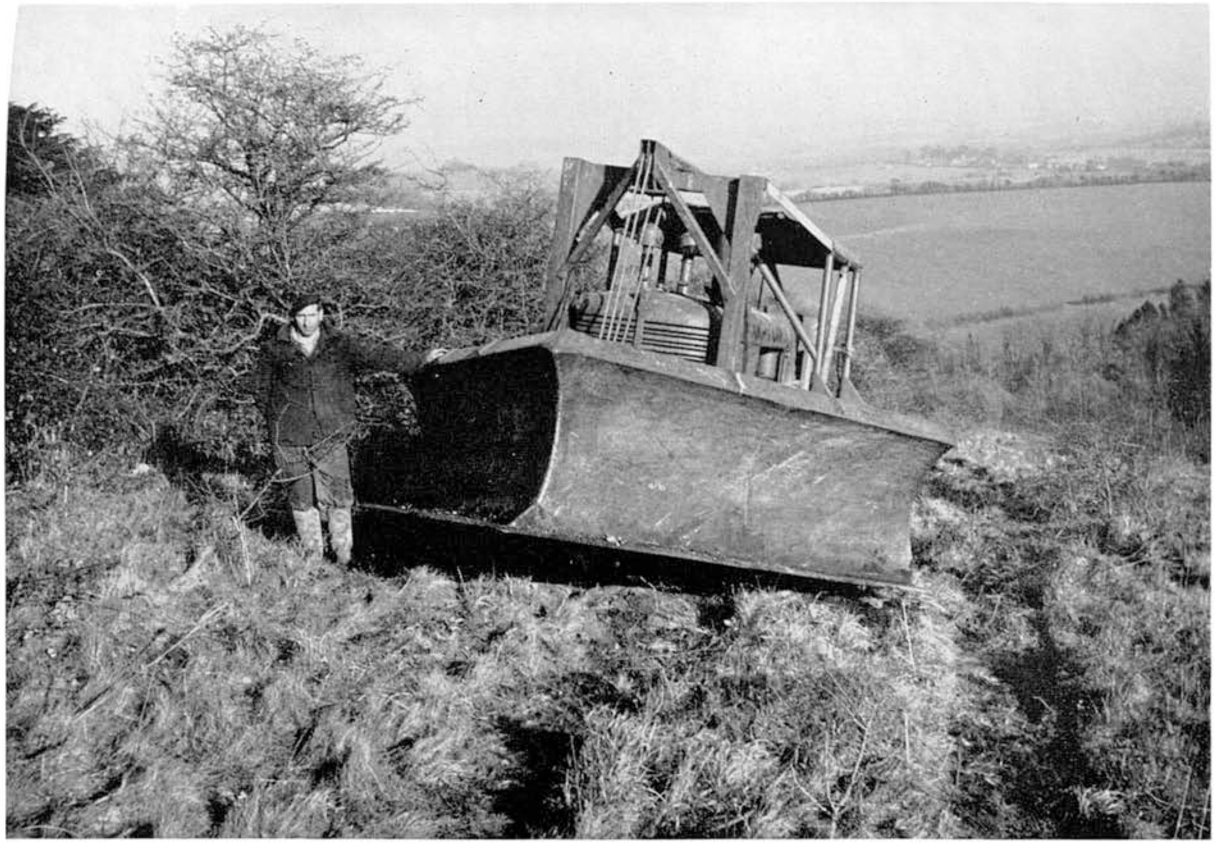


PLATE I. Miller: Derelict Woodland Investigations: V-blade Scrub Cutter at Queen Elizabeth Forest, Hampshire.

PLATE 2. Miller: Derelict Woodland Investigations: Strip, twelve feet wide, cleared by V-blade Scrub Cutter in Mixed Coppice at Marelands, Alice Holt Forest, Hampshire.

PLATE 3. Levisohn: Researches on Mycorrhiza: Effects of two different mycorrhiza-formers on seedlings of Norway spruce and birch. Upper picture: pit inoculated with *Boletus scaber*. Lower picture: pit inoculated with *Amanita muscaria*.

PLATE 4. Faulkner: Experiments on Chloropicrin: Tractor-mounted Gravity-feed Constant-head Injector for Applying Chloropicrin to Seedbeds.

phosphorus, are lowest under the manured trees, which are showing vigorous growth. The upper layers of peat under unmanured trees show values intermediate between the manured trees and unplanted ground; at greater depths the amounts are not appreciably different from those in the unplanted ground. The roots of the most vigorous manured trees have penetrated to the underlying moraine in places where the peat is less than eighteen inches deep, and the drying effect on these shallower peats is very pronounced.

This observed depletion of potassium reserves in the peat under the larger trees suggests that the yellow colour of the foliage, which is often particularly noticeable during a dry autumn, may be due to potassium deficiency. Analysis of foliage collected in September 1956 from lodgepole pine and Sitka spruce (Experiments 128 and 49), indicated a positive correlation between height growth and levels of nitrogen, potassium, and magnesium in the foliage of both species in plots which had received added phosphate, suggesting that these elements were likely to limit growth in larger trees whose initial phosphate requirements had been satisfied. A factorial manuring trial similar to that at Culbin was accordingly laid out in plots of both these species (Experiments 128 and 79) in April, 1957, to test the effect of applications of these three nutrients on the growth of both species.

In view of this possible need for added potassium in older plantations on deep peat, the use of granite dust as a slow-acting potash fertilizer is being studied. Preliminary analyses suggest that appreciable amounts of acid-soluble non-exchangeable potassium are contained in the <0.5 mm. fraction of crushed Rubislaw (Aberdeen) granite.

Soil Studies in Thinning Plots

The investigation of the effect of thinning on some physical and chemical properties of the surface soil in the Norway spruce sample plots at Bowmount Forest has been completed (cf. *Forestry*, Vol. XXX, 1957). The unusually light B grade thinning has been shown to result in increased litter fall and accumulation of organic matter on the forest floor, but differences in litter fall between the heavier grades are small, due to changes in crown development. Thinning greatly increases the rate of breakdown of the forest floor and the amount of nutrients available per tree. The surface soil under the B grade thinning contains more carbon, organic phosphorus, and "available" calcium, but leaching of potassium is more intense than under the heavier grades.

The Effect of Cropping Systems on Forest Nursery Soils

Arrangements have been made for the annual collection of soil samples from the long-term fertility maintenance demonstrations at Newton, Inchnacardoch and Teindland (Woodland) Nurseries, with the object of studying the long-term effects of the different cropping systems, particularly greencropping and the use of raw hop waste, on the structure and nutrient content of three widely-differing types of Scottish nursery soils. Results from the first season's samples show the value of hop waste in the retention of nutrients in a readily-soluble form, particularly in the coarse-textured soil of the woodland nursery.

COPPER DEFICIENCY IN POPLAR

By BLANCHE BENZIAN

Rothamsted Experimental Station, Harpenden, Herts.

232:322.42

In 1955, "needle tip-burn" on Sitka spruce seedlings grown at Wareham was shown to be due to copper deficiency. The black discoloration of the leaves of poplar cuttings (*Populus robusta* hybrids) grown on the same soil has now been diagnosed as a deficiency of the same micro-nutrient. The symptoms were greatly reduced by a soil application of a fritted trace element material containing iron, manganese, copper, zinc, molybdenum, and boron, and also by foliar sprays of copper given as a lime-copper sulphate mixture. Table 22 shows scores for blackening, height in inches and copper content of the poplar leaves.

Table 22

Effect of Copper on Poplars

	Scores for blackening	Height in inches	Copper in leaves: parts per million in dry matter
No fritted trace elements	9	20.6	1.3
With fritted trace elements	2	29.8	3.1
No copper foliar spray	8	18.6	1.8
With copper foliar spray	2	33.1	4.2

FOMES ANNOSUS IN EAST ANGLIA

By Dr. J. RISHBETH

Botany School, University of Cambridge

443.3

The effectiveness of large-scale creosoting, designed to prevent surface infection of pine stumps by *Fomes annosus*, has been tested in eight plantations (*Report on Forest Research*, 1956). Control was moderate to good, its efficiency averaging 81 per cent when based on the reduced area of stump section colonized by the fungus, but was not as complete as that recorded in an earlier experiment. This may partly be due to the fact that the type of creosote differs from the one used before. Experiments have shown that some creosotes are more effective than others, but the reasons for this are not yet known. For a variety of creosotes, heavy applications are more effective than light ones, and partial failure in practice is doubtless often due to an insufficiently heavy application. With pines, resin exudation from the stump surface may limit or prevent creosote penetration where application is delayed. Protection also tends to be incomplete when any irregularities on the stump surface are not adequately creosoted. The effectiveness of creosote for protecting stumps of Douglas fir and European larch is being tested.

The surface tissues of stumps can be killed by applying certain chemicals directly after felling. This allows rapid colonization of the stump surface, particular chemicals tending to encourage growth of specific fungi, and basidiomycetes such as *F. annosus* with a limited ability to compete with other fungi are often suppressed. Amongst the more promising chemicals tested are polybor-chlorate and ammonium sulphamate, applied respectively as 20 and 40 per cent aqueous solutions. If it can be shown that the resulting active growth of fungi prevents a major spread of *F. annosus* within a stump from portions already infected, this type of stump treatment may prove useful in replanting areas where the parasite is well established.

A preliminary survey has been initiated of the occurrence of *F. annosus* basidiospores on conifer foliage in certain British forests, there being reason to believe that this provides some measure of local spore production.

Some further observations on *F. annosus* have been published in *Forestry*, 30, 69-89, 1957. A preliminary note on the surface microflora of pine needles appears in *Nature*, 179, 682-683, 1957.

ECOLOGY OF FUNGI COLONISING CONIFEROUS STUMPS IN EAST ANGLIA

By D. S. MEREDITH

Botany School, University of Cambridge

443.3

The fungal ecology of coniferous stumps has previously received little attention, except for studies on *Fomes annosus*. The present investigation has proceeded along two major lines, the nature and extent of competition between *F. annosus* and other fungi in stumps, and a study of stump infection by fungal spores.

At monthly intervals during 1956 two widely separated compartments in Thetford Chase were thinned for the first time. Half the stumps received no treatment and the other half were creosoted immediately after felling, the latter stumps acting as control in excluding air-borne basidiospores. After five months the stumps were sampled in order to determine the seasonal variation in incidence of stump infection under natural conditions. The frequency of infection by *F. annosus* increased during and just after the spring drought, whereas the number of stumps infected by *Peniophora gigantea* decreased sharply. The decrease of *P. gigantea* was correlated with the disappearance of sporophores, but some stumps were always infected and the controls conclusively proved that this was not due to infection through the roots. Sporophores of *F. annosus* could always be found during drought, and there is some evidence that spore production continues in such periods and only ceases below freezing point. The wet summer of 1956 caused *P. gigantea* sporophores to appear early, and stumps produced after June showed a high incidence of infection with this fungus. Conversely the number of stumps infected with *F. annosus* decreased, partly owing to its rapid replacement by *P. gigantea*.

The monthly thinning experiment showed that even when sporophores of *P. gigantea* were not present, this fungus still colonised a proportion of stumps. It was thought that a considerable reservoir of fungal spores might survive on needles of standing trees, and preliminary washings of needles pipetted onto wood discs clearly demonstrated this. After 12 to 14 days' incubation, fungal colonies developed, and could be identified by conidial form and mycelial characters: *F. annosus*, *P. gigantea*, *Stereum sanguinolentum* and several blue-stain species were amongst the fungi isolated. Considerable numbers of spores of these fungi may be carried by rain-splash onto stump surfaces, and the presence of this reservoir of spores could explain the infection of stumps by *P. gigantea* when sporophores are absent, infection occurring as a result of occasional showers in a predominantly dry spell of weather. Experiments are now in progress to determine how long spores of various species remain viable on needles.

RESEARCH ON KEITHIA THUJINA

By R. G. PAWSEY

Department of Botany, University of Nottingham

443.2

Observations on the life history of *Keithia thujina*, a fungal pest of *Thuja plicata*, up till April, 1956, indicated that two mechanisms were probably involved in carrying infection through the winter. These were (a) the over-wintering of dormant spores on the surface of the leaves, or of minute unobserved stages of infection developing after inoculation in the late autumn; and (b) the overwintering of early growth stages of apothecia, which with the onset of warmer conditions in the spring, developed to maturity and discharged their ascospores.

The development of these incipient apothecia was followed after the introduction of nursery plants into the greenhouse, and discharge was observed after about two weeks. The overwintering by means of incipient apothecia, although confirmed experimentally, was apparently not responsible for the heavy infection which appeared in the experimental nurseries at Nottingham during the early part of May 1956. In these nurseries heavily infected plants from the Forest of Dean had been lined out in November 1955, in close association with uninfected plants from Devilla, Fife, and Kinver, Staffordshire. The heavy infection in May 1956 was confined entirely to the previously infected plants, and no spread was observed on to the introduced uninfected plants, even though at the edge of adjacent blocks of infected and uninfected plants, the foliage of these plants was actually in contact.

Small numbers of mature apothecia were observed on the nursery plants during April. If these were removed and brought into the laboratory it was confirmed that these apothecia were actively discharging ascospores, but the results above indicate that this potential inoculum was insufficient to infect the previously clean plants.

During April, a small vaned spore trap was erected in the University nursery. This carried a greased slide which was held vertically and directed continuously into the wind. The slide was changed daily. Careful inspection of these slides and also of similar slides exposed horizontally six inches above the soil, failed to reveal the presence of ascospores of *Keithia* in the air. However no *Keithia* ascospores were trapped on these slides, even after the development of heavy infection during May and June.

The heavy infection restricted to previously infected plants was evidence that the inoculum was already present on the plants before lining out at Nottingham, in November 1955. This infection could not be related to spores discharged from mature apothecia which had overwintered in the incipient condition.

An automatic volumetric spore trap was kindly loaned by Dr. J. M. Hirst of Rothamsted Experimental Station. This was placed in the University nursery and kept running continuously from 22nd June until 21st July, during which time mature apothecia produced from the new infection were known to be discharging. Continuous records were kept of temperature, humidity and rainfall during the same period. With this apparatus it was hoped to relate ascospore discharge to climatic conditions, as well as obtaining valuable information on the nature of the general air spora. The slides exposed were very carefully analysed but no ascospores of *Keithia thujina* were recorded. These would be easily recognised, if present, even in the heavy deposit of spores of other organisms. Apparently the dispersion of ascospores from the infected plants in the small nursery was so great that the use of this trap was not effective in showing their presence in the surrounding air.

Analysis of the spore catch, although of no significance with respect to *Keithia*, produced interesting data on the diurnal changes in the general spore content of the air. Detailed results have been obtained for *Cladosporium*, dark and hyaline basidiospores, and smut spores, which to a large extent confirm previous experiments by Dr. Hirst.

During the winter of 1956-57, infected transplants of *Thuja plicata*, aged two-plus-one, were transferred from the nursery into the greenhouse, at regular intervals. On these plants it was again confirmed, by plotting the distribution of incipient apothecia, and by following their development, that these structures matured rapidly and active discharge of ascospores took place after about a fortnight. It was not found possible to substantiate experimentally the circumstantial evidence of the previous year, that ascospores or some other minute dormant phase was performing the main function of overwintering. Plants brought into the greenhouse did not show new heavy infection, which was a characteristic feature after four to six weeks on plants similarly treated during the winter of 1955-56. On some plants new infection was observed, but that was very light and occurred only spasmodically. However, in early May 1957 heavy new infection was observed at nurseries at Tintern and Gwydyr, which was comparable with that produced in the nurseries at Nottingham in May 1956.

In co-operation with Mr. Murray and the staff of the Commission's Research Branch pathology section, spraying experiments were started at Tintern and Gwydyr in October and November 1956, the results of which are now being assessed.

Microtome examination of early stages of infection indicates that penetration takes place directly through the unbroken epidermis, and not through the stomata.

Research has been continued on the factors affecting the discharge of ascospores. In laboratory conditions, at humidities very close to saturation, discharge from mature apothecia takes place continuously. If the surface of the apothecium is dried rapidly during this slow continuous phase, the rate of discharge is greatly increased momentarily. If saturated conditions are then re-established no discharge is recorded for a considerable time.

During June and July 1956, greased coverslips were mounted above mature apothecia on plants in the nursery. This work gave some evidence that discharge is heaviest during and following rainfall, and is much less marked during the period of maximum atmospheric humidity in the early morning. The plants on which these experiments were carried out were large transplants aged two-plus-one-plus-one, and discharge activity on smaller more-densely foliaged plants is probably very different.

Discharge of ascospores from apothecia removed from the plant has been recorded to a height of five mm. above the surface of the apothecium.

Attempts have been made to prepare a concentrated suspension of ascospores for inoculation experiments. This can be successfully accomplished, provided that the surface on to which the spores are dropped is covered by a thin film of water, and is not allowed to dry out. Once drying has taken place the spores become very firmly attached to the leaf surface, glass and cellophane etc., by means of a gelatinous sheath on the outside of the ascospore. Washing inoculated foliage to remove spore deposit is ineffective, no matter how vigorous the treatment. Washing in dilute concentrations of detergent solution is similarly ineffectual. It was found that spores adhering to a glass surface withstood a strong jet of water which was directed on to them for several hours. Vigorous shaking of up to two hours in 5 per cent "Teepol" solution failed to remove the majority of the spores.

A number of successful inoculation and infection experiments have been carried out, but it has not been possible so far to elucidate critical conditions controlling infection. Apparatus is being built to facilitate inoculation and incubation over a range of temperatures from 5 to 20°C, under constant conditions of artificial lighting.

STUDIES ON MERIA LARICIS, NEEDLE-CAST DISEASE OF LARCH

By P. BIGGS

Botany Department, Southampton University

443.2

Further work on the problem of Needle-Cast of larch, *Meria laricis* Vuill., has been undertaken. This has involved, during the past year, both experimentation and the analysis of disease data provided by Forestry Commission Nurseries.

The Fungus in Culture

Further isolations from diseased material sent from various Forestry Commission nurseries throughout the country have been made. By examination of single spore cultures of these isolates and comparison with 1955 isolates, the original number of eight recognizable strains (*Research Report*, 1956) has now been reduced to four. These are separable by numerous cultural characteristics, including type of mycelium (smooth or fluffy), number of spores and discoloration of medium. Preliminary indications from experiments designed to determine the effect of environmental factors on the growth of this fungus, are that growth occurs over a wide range of conditions. Growth occurs at temperatures from 0-25°C, with optimum between 17-20°C, and within a pH range from pH 3.1-pH 10, with optimum between 5 and 7. Under any particular set of experimental conditions the various strains are separable by different growth rates.

As previously reported, the "a" strain of *Meria* was the strain most commonly isolated from diseased material in 1955. But, in recent isolations (Autumn 1956) the "b" strain has been found to be the most prevalent. The number of isolates of the "a+" strain remained constant throughout the two years, while the X strain has only been isolated once (Hybrid larch 1955).

Table 23

Isolations of Four Strains of Meria Laricis

Year	Tree species from which isolated	Number of isolations			
		Strain a	Strain b	Strain a+	Strain X
1955	European larch	5	1	1	—
	Hybrid larch	2	1	3	1
	Japanese larch	4	3	2	—
	Total	11	5	6	1
1956	European larch	0	7	1	—
	Hybrid larch	2	1	1	—
	Japanese larch	1	3	4	—
	Total	3	11	6	—

Spore Germination

Preliminary spore germination experiments, designed to give indications of the optimum conditions for the artificial inoculation of trees, show that *Meria* spores can germinate under a wide range of temperatures from 0-25°C with an optimum at about 17°C. Germination actually occurred at 0°C, but was very slow in commencing. Germination percentage is increased by employing Dox-yeast agar, instead of water agar, as the substrate. Sections of infected needles demonstrate that the spore germ tube enters the needle through the stoma.

Inoculation Experiments

Inoculation experiments with the four strains are still in progress, but the following trends are already evident.

(a) In artificial inoculation experiments, disease symptoms appear most rapidly on European larch, followed by appearance on hybrid larch and finally on Japanese larch. Infection dates supplied by Forestry Commission nurseries show the same sequence. The later development of disease symptoms on hybrid and Japanese larches may be due to the retardation of spore germination of *Meria* on these two trees or, on the other hand, to the slower growth of the pathogen within the needles of the hybrid and Japanese larches and consequent later development of visible symptoms. This problem is at present under investigation by means of a series of single spore inoculations of the two tree species.

(b) Inoculation with a particular strain of *Meria* has in no case given the same strain on re-isolation, indicating that the strains are unstable in the host, although stable in culture. Further experiments are planned to compare the resistance of each of the tree species to each of the four strains of the fungus.

(c) From Table 23 it can be seen that "a" and "b" strains of *Meria* can be isolated from all the three larch species. Isolates of a particular strain, from all the larch species, have so far shown identical pathogenetic and cultural behaviour, e.g. the "a" strain isolated from European larch is identical with the "a" strain isolated from hybrid and Japanese larches.

Preliminary analysis of data supplied by Forestry Commission nurseries

(a) Primary infection apparently occurs on European larch. There is no recorded case where *Meria* has been found on larch species other than European, if European larch is free of *Meria*. Also all noted "severe" attacks occur on European larch.

(b) Only one nursery (Davidstow, Wilsey Down Forest, Cornwall) shows *Meria* attack (on Japanese larch) in the absence of European larch.

(c) In 1956, six nurseries not infected in 1955 reported *Meria* attack, and in five of these infection was confined to European larch although other species were also grown.

Final analysis of these data is being withheld until the 1957 observations have been received.

Proposed Future Work

(a) Analysis of disease data of three years sent from the nurseries, together with weather data extracted from the Meteorological Office, in order to determine the nature of the correlation between specific weather conditions and the onset of the disease.

(b) A field experiment designed to obtain information regarding the spread of the pathogen, both among trees of the same species and trees of different species, is in progress. The dissemination of inoculum, in relation to particular weather conditions, is also being studied.

(c) Further studies on the fungus in culture, with a view to elucidating the status of the isolated strains and their possible distribution throughout the country, are envisaged.

RELATIONSHIP BETWEEN LARCH CANKER AND TRICHOSCYPHELLA WILLKOMMII

By Dr. J. G. MANNERS
Botany Department, Southampton University

Anatomical Investigations 443.3

The results of the anatomical investigation of cankers produced in European larch by inoculation with *Trichoscyphella willkommii*, or by local freezing, have been incorporated in a paper published recently (Manners, 1957). As indicated in a previous report, the two types of canker resemble each other closely when examined anatomically. The fungus appears to do most damage when the cambium is in a dormant state: in several trees inoculated with *T. willkommii*, in the absence of frost, the inoculation wound healed during the summer following inoculation, but the fungus killed a large area of cambium during the following winter, and a canker resulted.

The data obtained from the anatomical assessment of the cankers produced on trees inoculated at Penzance in 1951 or 1952, and harvested in 1953, have been analysed statistically. The analysis indicated that trees of European larch of origins known to be susceptible in the field to canker were more heavily cankered than trees of origins known to be resistant. Since field susceptibility is well known to be correlated with susceptibility to frost, there must therefore be a correlation between susceptibility to frost and susceptibility to the fungus. This may be the result of unconscious genetical selection in the past for resistence to both factors, but could be the result of a casual relationship between them, such as that postulated by Langner (1936), who suggested that the fungus entered through a frost crack and prevented subsequent healing of the crack.

Freezing and Inoculation Experiments

The trees of European larch locally frozen and inoculated in 1955 have been maintained in cold frames. Few signs of *T. willkommii* are apparent, and these trees are being refrozen (general, not local, frost), and re-inoculated in the same manner as previously, by spraying with a spore suspension or placing the tree beneath an active canker, bearing fruit bodies of the fungus. It is hoped thus to determine the effects of recurrent frosts on the persistence of cankers, both with or without the presence of *T. willkommii*. The results of a small preliminary experiment on these lines, carried out on trees inoculated in 1953, suggests that such frosts, though perhaps insufficient to damage the tree as a whole, may cause more or less dormant cankers to become active again.

Preliminary results from the 1956 experiments on European larch (planned on the same lines as the 1955 series) confirm those obtained from the earlier year's work. Trees of a Polish (Kracow) origin proved more resistant to frost than trees of a Scottish (Moray) origin, the trees of both sets being of approximately the same size. Of 48 trees frozen, 19 developed frost cracks by May 1957, while in 3 others lateral shoots were killed. Japanese larch showed little more resistance to frost than European larch.

Taxonomical Studies

The preparation of material for a revision of the British Trichoscyphelloideae has reached an advanced stage, and there are now only a few outstanding problems. Type material of a number of continental and North American species has been examined morphologically and anatomically. The anatomy of apothecia of species of the "*fuscosanguinea*" and "*lachnellula*" groups (including members causing conifer cankers in North America) has been investigated for the first time, and it has been confirmed that they are closely related to other members of the sub-family.

REFERENCE

LANGNER, W., 1936. Untersuchungen uber Larchen, Apfel und Buchen —Krebs. *Phytopath. Z.* 9, 111-145.

MANNERS, J. G., 1957. Studies on Larch canker. II. The incidence and anatomy of cankers produced experimentally either by inoculation or by freezing. *Trans. Brit. mycol. Soc.* 40, 500-508.

STUDIES ON THE PHYSIOLOGY OF FLOWERING IN FOREST TREES

By P. F. WAREING and K. A. LONGMAN
Department of Botany, University of Manchester

181.521

The development of forest genetics has focussed attention on problems of flowering in trees, since the overall rate of progress in breeding work is generally limited by the occurrence of a "juvenile" period, lasting from several to many years according to the species, before flowering can occur. Clearly methods of inducing early flowering in such seedlings will be of great value to the practical breeder. The induction and control of flowering is similarly of paramount importance in the development of seed orchards, even where grafted material from flowering trees is used. The development of a practical programme for flower induction and control is dependent upon adequate knowledge regarding the physiology of flowering in trees, but unfortunately there is a great lack of fundamental knowledge of this subject. The present investigation constitutes an attempt to elucidate various aspects of the physiology of flowering in trees, in relation to the practical problems outlined above.

Two major aspects of the problem may be distinguished viz. (1) the effect of various *internal* conditions within the tree itself, and (2) the effect of various *external* factors, on flowering. These two aspects have to be considered both in relation to the transition from the juvenile to the adult condition, and also in relation to the maintenance of flowering in the adult tree. Experiments have been set up to investigate these various aspects of the problem, using both seedlings and grafted material from flowering trees. The main species being investigated are Scots pine, lodgepole pine, Japanese larch, birch and beech.

The effects of various external factors on flower formation are being examined, but special attention is being paid to the effects of day-length and gravity. It is well known that daylength conditions markedly affect the flowering of both herbaceous and shrubby species, but owing to the difficulty of experimental photoperiodic treatment of mature trees, it is not known whether daylength affects the flowering of forest trees. By using grafts of material from flowering trees, however, experimental control of daylength conditions is greatly facilitated, and the effect of various photoperiodic treatments is being investigated in the species enumerated above. Attempts are also being made to reduce the duration of the juvenile phase by photoperiodic treatment.

The possibility that geotropism may play an important part in the growth and flowering of trees is suggested by the horticultural practice of tying down branches of fruit trees (as in the "spindle bush" method), which is said to reduce growth and promote fruit bud formation. Experiments with birch have shown that seedlings placed horizontally make markedly less growth than do vertically-grown ones. A detailed study of the distribution of male flower buds in a number of branches of larch suggests that the formation of flowers is affected by the position of the bud in relation to gravity. Male flower buds are found predominantly on the under side of horizontal twigs, and on all sides of trailing shoots. These observations have been followed up by experiments in which shoots of larch have been arranged in various positions in relation to gravity, to determine whether flowering can be induced by appropriate geotropic treatments.

Experiments with Scots pine include the effect of nitrogen, phosphorus, and potassium fertilizers on the age at which female cones are produced by seedling trees, and the effect of pruning, disbudding, training of branches, girdling, etc., on the initiation of male flowers.

NOTES ON THE ECOLOGY OF ASH

By P. WARDLE

Botany School, University of Cambridge

181:182

An investigation into the ecology of the common ash, *Fraxinus excelsior*, was made at Cambridge between 1954 and 1957, the work being aided by a grant from the Forestry Commission. The object of the investigation was two-fold: to provide an outline of the whole subject of the autecology of the ash; and to provide more detailed information about certain problems, particularly those connected with regeneration. Measurements of the size and growth rate of ash plants were made at many localities in the British Isles. More intensive field work, which included recording the survival rate of seedlings and seeds, was carried out in East Anglian woods. Some environmental factors, such as light intensity, were measured; but the measurements were not sufficiently comprehensive to enable the differences between any two sites to be expressed on a completely quantitative basis.

A series of experiments with ash seedlings tested the effect of the density of the overhead canopy on the growth rate. Other experiments tested the effects of soil acidity, nutrient concentration, water supply, and competition from grasses. The remainder of the report summarises the conclusions which were reached.

A succession of predators and parasites reduce the number of ash seeds which eventually germinate. The caterpillar of *Argyotoza conwayana* kills seeds while they are still on the trees, and rodents eat seeds which have fallen to the ground. When the seeds fall, the embryos are only half-grown, and eighteen months usually elapse before germination occurs. Many seeds rot during this time. Despite the hazards however, newly germinated ash seedlings appear in abundance during April and May in most years, since the trees fruit prolifically.

The compensation point of ash seedlings was found to be at a daylight factor of about 9 per cent. Under dense dog's mercury, *Mercurialis perennis*, the light intensity is below this minimum, and ash seedlings which germinate here soon disappear, usually as a result of being attacked by damping-off fungi. Slowly-growing seedlings do persist where the *Mercurialis* itself is shaded out by the tree and shrub storeys. Because they open their buds one or two weeks earlier than the canopy trees, they are able to complete their growth before the light intensity falls below their compensation point. The successful regeneration of ash depends on the presence of these suppressed ash seedlings, which commence rapid growth if gaps are formed in the canopy. Natural woods dominated by ash occur where soil dryness (e.g. South Downs) or soil instability (e.g. Derbyshire dales) favour ash seedlings at the expense of the field layer. In a drier wood without a field layer of *Mercurialis*, a large proportion of seedlings died during their first winter, but the cause was not discovered.

The influence of soil factors and water balance upon ash was studied on plants growing in the optimum light intensity, i.e. full sunlight. A poor water balance, caused by either soil dryness or exposure of the top to drying winds, reduces the growth in height and girth. Under extreme conditions ash remains a low shrub. Ash is absent on soils with a pH below 4.2, because its roots do not tolerate such acidity. The altitudinal limits of ash are set probably by the acidic soil conditions rather than by the climate. Good sites for ash occur over a pH range of 5 to 8, though chlorosis is sometimes seen on basic soils.

Ash roots are concentrated in the top 10 cm. (four inches) of soil. Below this they are sparser, though a few may penetrate to great depths. Most of the fine rootlets live only one year. They are borne on coarser roots which grow rapidly and persist indefinitely. The coarser roots tolerate periods of water-logging, but the suppression of the fine rootlets by a high water table produces symptoms of drought in the trees.

Ash readily invades grassland (except in frost hollows), entering where the continuity of the sward is broken. Thick grass was found to reduce the growth rate and survival of the small seedlings.

MORPHOLOGICAL VARIATIONS IN CONIFERS

By Dr. E. V. LAING

Department of Forestry, Aberdeen University

Pseudotsuga—Douglas firs 165.51

The more intensive study of the variations in the genus *Pseudotsuga* has been continued. *Pseudotsuga taxifolia* shows pronounced differences in the shape of the tips of the needles, the arrangement of the needles, the presence or absence of stone cells in the leaf and their size if present, presence or absence of hairs on the shoots, the continuity of the hypodermis and the form of the bract scales of the cone.

One of the most interesting variations is where the needles have very broad tips, which can be definitely bifid. This latter feature is always associated with the Douglas firs of Japan and China such as *P. diversifolia*. The leaves of such trees also contain the large stone cells of the Eastern species. There is agreement in these respects with *P. glauca*, but the trees are distinct in that the cones have very exerted bracts, resembling those *P. caesia*. There is almost complete agreement with the *P. vancouveriensis* of Flous. One such notable tree—one of the oldest and largest—is growing in the Policies of Durris House near Aberdeen.

Another very distinct tree which is found to be common in our woods can be placed as *P. merrilli* (after Flous). It has glabrous twigs. It is usually of very fine form. *P. glauca* itself shows variations in the hypodermis and the shape of the leaf tip.

From the present investigation it is appearing that there is a series of gradations from the true Green Douglas fir through *P. vancouveriensis* to the Blue Douglas fir and so on to the species of Japan and China.

These variations have been used to construct tentative keys for *Pseudotsuga*, both for vegetative characters and cones.

Not only do these variations often agree with tree form, but they may be useful in separating trees from the point of view of disease incidence.

Picea—Spruces

Due to the availability of coning material amongst the spruces, the opportunity was taken to construct keys by which species could more readily be identified.

SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY

Rothamsted Experimental Station, Harpenden, Herts.

114.67

Work has continued on a study of the fauna associated with recently fallen tree litter. There is increasing evidence of a sequential pattern in organic-matter decomposition, with a succession of fauna and flora associated with it. Present studies are directed to this aspect in order to determine whether successional biological phases occur in decaying leaves, and if so the species associated with each stage.

A major problem in these investigations is the difficulty of ascertaining the age of leaves used as experimental material. A partial solution would be to collect recently fallen leaves, but it is difficult to maintain these in conditions comparable to those occurring in the natural milieu. The writer has explored the possibility of marking leaves with a radioactive isotope, and a pilot experiment using this technique was commenced in October, 1956. Beech leaves were marked on the trees with an artists' oil colour to which had been added Tantalum 182. Preliminary results suggest that this technique is a promising means for recovering leaves of known age, but the effect of the isotope on the living inhabitants of the leaves has yet to be ascertained.

Laboratory studies of the soil meiofauna have continued. The writer collaborated with Mr. C. C. Doncaster of the Nematology Department, Rothamsted Experimental Station, in certain aspects of a study of predators of nematode adults and cysts. Using a laboratory culture technique devised by the writer, it was found that certain members of the soil meiofauna, especially the spring-tail *Onychiurus armatus* (*s. lat.*) (Tullb.) fed upon cysts and adults of *Heterodera cruciferae* Franklin and other nematodes. Other Collembola including *Isotoma viridis* Bourlet, *Hypogastrura* sp. and *Orchesella villosa* (Geoffroy) fed on cysts. Mesostigmate mites also fed to some extent on egg sacs of *H. cruciferae*. *O. armatus* was the most important predator cultured, and was also found to prey upon inactive nematodes of the genera *Dorylaimus* and *Mononchus*. A paper describing the results of this investigation is now in the press.

SOIL COLLEMBOLA IN A DOUGLAS FIR PLANTATION

By T. B. POOLE

University College of North Wales, Bangor

114.67

Since there has been no previous published account of the ecology of soil collembola in a British woodland, it was felt that an intensive study of these animals would be worthwhile. Furthermore the author had the opportunity to work as a member of a team of zoologists studying different groups in the fauna in this one environment. The habitat selected was a 25-year-old Douglas fir plantation near Bangor, Caernarvonshire, since there was a complete canopy with no ground flora and it was felt that such a plantation would provide relatively uniform conditions.

Experimental Work

The contents of the gut of all the common species were examined in order to gain some insight into the part played by collembola in the breakdown of the leaf litter. Quantitative estimates were made of the different identifiable material in the alimentary canals of not only the different species of collembola but also for the same species at different times of the year. Fungi were cultured from the fresh faeces of *Tomoceros longicornis* (Muller) Lubbock, showing that viable fungi can pass through the collembolan gut. I am grateful to Dr. S. G. Jones for his help and advice on the culture of fungi. In the light of these examinations work was continued on the methods for culturing collembola.

To supplement previous field work, an investigation was made of the vertical distribution of the collembola in the deeper layers of the mineral soil in two areas of differing soil texture.

Theoretical Work

An analysis was made of data collected during the previous two years. The following is a brief account of the analyses carried out and gives some indication of the nature of the previous work.

Summary of Results

The soil collembolan population in a Douglas fir plantation in North Wales was estimated to be approximately 47,000 per square metre; this must be regarded as a minimum figure. The organic layer, which includes both the litter and raw humus layers, was approximately one inch in depth and contains 85 per cent of the population.

In spite of the relatively uniform appearance of the environment, it was shown statistically that the populations of collembola exist in distinct aggregations, and this has necessitated the transformation of the collembolan data into logarithms before further statistical analyses could be performed.

Attempts were made to correlate the numbers of collembola with some of the environmental factors, and in many cases significant results were obtained, e.g. it was shown that the moisture content and depth of the organic layer influenced the numbers of these soil animals so that areas with a deep moist organic layer would have a high population.

Owing to windblow, the experimental area had to be altered half way through the year's sampling programme to a new area some 100 yards further over in the plantation. A comparison of these two areas showed interesting and unexplained differences in physical factors, numbers of collembola and species composition.

Graphs have been prepared to illustrate the variations in numbers and vertical distribution of the common collembola over a period of twelve months. Although this period is too short, and therefore the data too meagre, to allow for speculation on the causes of these changes, it was possible to show that the species composition was significantly different in the last month, as compared with the first month of sampling. The year of sampling had an exceptionally wet summer, and the collembola had a maximum population in August, which is a time when some other workers have shown them to be at a minimum. Studies in the vertical distribution of the soil collembola showed that different species have different vertical distributions, and that the depth of penetration of a species into the mineral soil is determined by the compactness of the soil and the size and morphological adaptations of the collembola.

A series of transects taken from tree bases showed that the populations of two of the common collembolan species (comprising some 54 per cent of the population) increased with distance from the tree. This gradient was related to similar variations in the depth and moisture content of the organic layer. These results were interpreted on the basis of the arrangement of the tree canopy so that the arrangement of the trees influences the pattern of distribution of the soil collembola in the forest floor.

Examinations of the solid food in the collembolan gut shows that the larger forms feed on soil fungi and occasionally leaf litter, whereas smaller forms appear to feed directly on the humus. Apart from forms feeding solely on fluids, there appeared to be no specific differences in feeding habits.

The soil collembola undoubtedly play an important role in litter breakdown by feeding on soil fungi and humus, and possibly by also acting as vectors for fungal spores. The large numbers of collembola recorded suggested that they exert an important influence in the acid soil of a coniferous forest.

EFFECTS OF THE PHYSICAL ENVIRONMENT ON THE DEVELOPMENT OF THE PINE LOOPER, BUPALUS PINIARIUS

By Dr. N. W. HUSSEY

*Department of Agricultural and Forest Zoology, Edinburgh University

Introduction

145.7:151.1

In view of the severe damage to Scots pine stands often caused by *Bupalus piniarius* L. (Lepidoptera: Geometridae), in Central Europe, it is surprising that there has been little laboratory research into the effect of the environment on the developmental stages. The observations recorded in this paper were made in an endeavour to fill this gap in our knowledge and in order to test the author's hypothesis on *Bupalus* bionomics advanced in an earlier paper (Hussey 1955).

The continental literature contains abundant evidence of the tendency for outbreaks to occur in warm, dry sites where the local climate has exaggerated these conditions for several successive years. Whether this apparent correlation is due to the fact that Scots pine is found chiefly on such sites or whether there is, in fact, a definite meteorological optimum for the pest, has never been established. The results reported here suggest certain trends which may present a clearer picture of the forces controlling *Bupalus* populations when additional information on the biotic control factors is available.

Adult longevity

Escherich (1931) mentions the importance of light winds and bright sun for adult flight and that, in the absence of such conditions, the moths remain motionless on the ground or foliage. Obviously, therefore, the capacity of the

*(Now at Glasshouse Crops Research Institute, Littlehampton, Sussex.)

adults to live through periods of cool, wet and windy weather after emergence is very important if the number of females fertilised, and hence the number of viable eggs laid is not to be severely reduced.

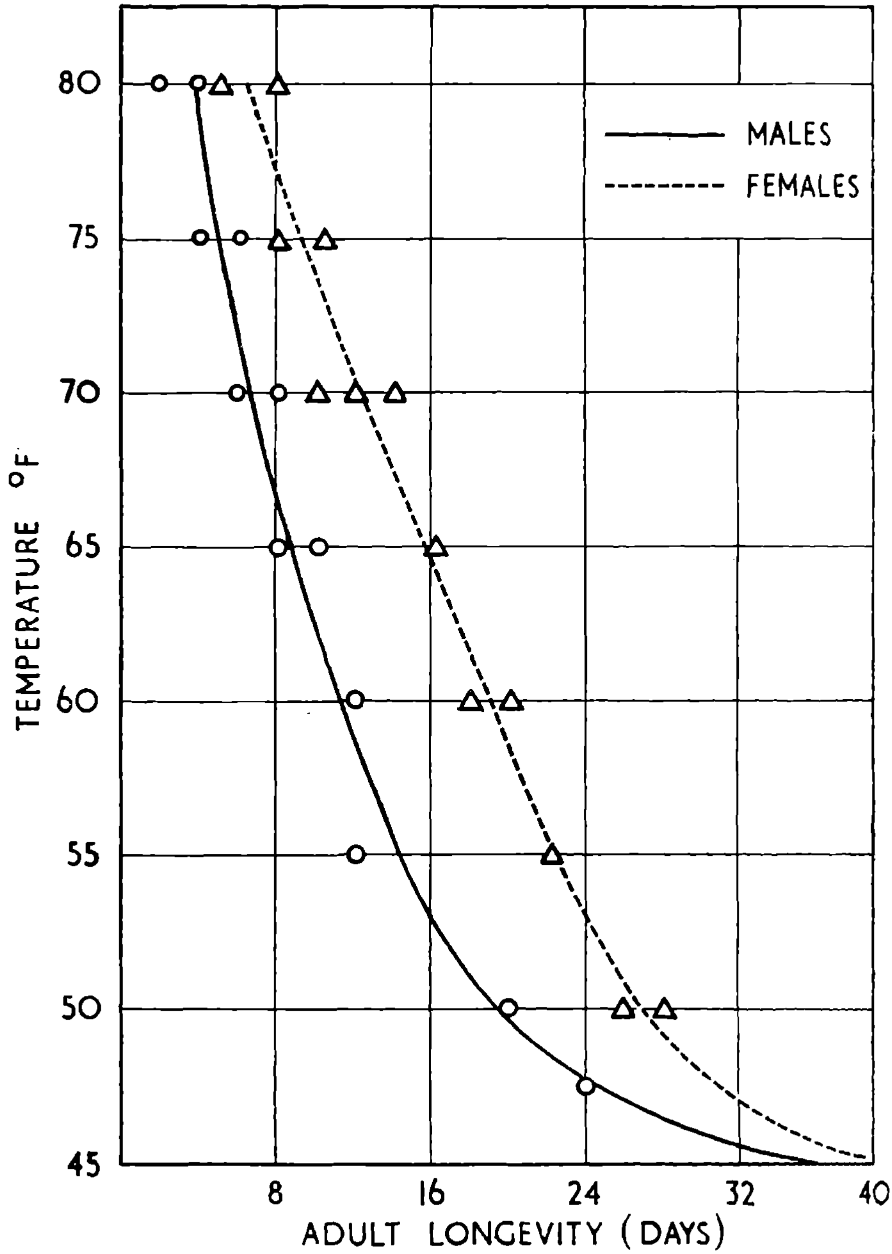


FIG. 2. Longevity of adult male and female *Bupalus piniarius*, at constant temperatures.

From Fig. 2, it will be seen that males have a rather shorter life than females at all temperatures, and that the longevity increases rapidly over the lower temperature range. It is also significant that those adults kept at 45°F for 37 to 39 days were capable of fertilisation and oviposition directly the temperature was raised above 52°F. Continental experience suggests that the only important mortality factor causing premature death of the adults is heavy rain, which has been recorded as beating many of the moths to the ground. It would appear, therefore, that, except in an abnormal year, a high proportion of emergent adults are capable of surviving until environmental conditions permit normal oviposition.

Oviposition

Only Brandt (1936) who studied the relation between pupal weight and fecundity, has worked on oviposition in *Bupalus;* but there are numerous references to the maximum fecundity of individuals.

The object of the present study was to observe the effect of variations in temperature and humidity on oviposition. As it is well known that heavier pupae give rise to females with above average fecundity, it was desirable to select females reared from pupae of the same weight for the experiments. This did not prove feasible through lack of material, and so the proportion of the eggs produced in the ovarioles which were actually laid by individual females has been taken as the basis of comparison between the treatments. Pairs were isolated in 2 lb. Kilner jars, with muslin-covered necks, inverted over crystallizing dishes containing salt solutions (Schuch 1952) to maintain the required humidities. An oven-dried shoot of Scots pine was placed in the test chamber to provide the females with an oviposition site which would not affect the humidity. Earlier experiments had shown that females would lay equally well on dried as on fresh shoots. The whole apparatus was maintained within thermostatically-controlled temperature cabinets.

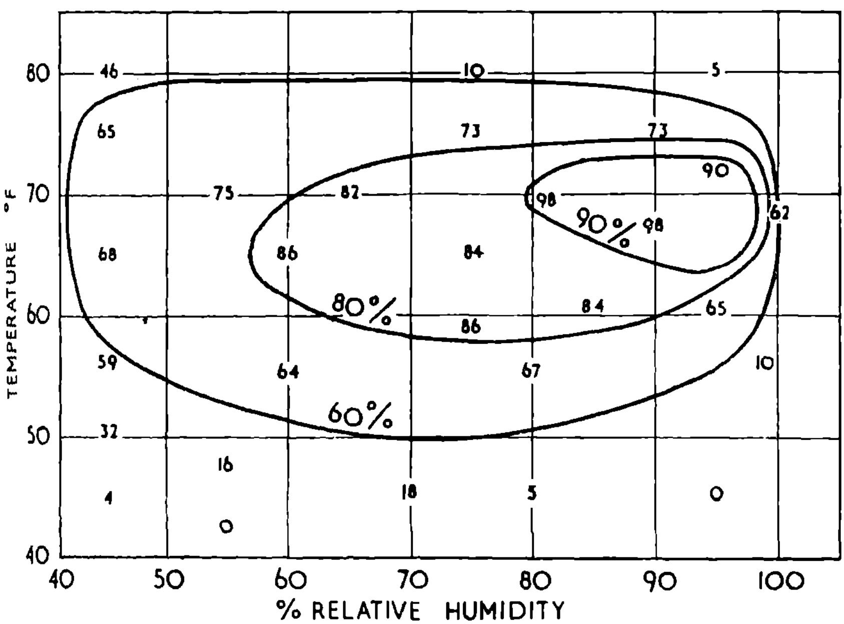


FIG. 3. Percentage of total number of eggs produced in the ovarioles *actually laid* by female *Bupalus piniarius* under different conditions of temperature and humidity.

In Fig. 3, the percentage of the ovariole contents actually laid has been plotted against the appropriate temperature and humidity, and the approximate isometric lines for 90, 80 and 60 per cent indicated. From these results we may infer that a high proportion of the available eggs will be laid when the temperature is between 64° and 73°F, and the humidity between 79 and 95 per cent, which represents a range of Saturation Deficiency of 0.5-3.0 mm. of mercury. Below 60°F, the oviposition rate declines rapidly to the threshold of 52°F. Though a few eggs may be laid below 52°F, they are produced haphazardly and singly, instead of in the regular rows of 10 to 20 associated with more suitable conditions.

As Zwolfer (1931) found in *Panolis*, egg production was restricted at high humidities.

Egg Hatching and Mortality

The incubation period of *Bupalus* eggs is, as demonstrated by Schwerdtfeger (1930) and Schwenke (1953), positively correlated with temperature. The present data give an essentially similar curve to that obtained by the earlier workers (Fig. 4). 100 per cent relative humidity delays hatching up to 1½ days, as found by Schwenke. The figures in Table 24 suggest that this retarding effect is more marked in the lower temperature range. From this table, Fig. 5 has been derived to illustrate the range of conditions associated with the lowest lethal effects; and these seem to lie within a more restricted range than has been found in *Panolis* (Zwolfer 1931).

Larval Development

One of the unusual features of the life-history of Bupalus is the irregular duration of larval life. Escherich (1931) states that under average field conditions the larval stadia are complete in three months, but on occasion only four instars, instead of the normal five, occur; and pupation then takes place after 84 days. The fifth instar is very irregular and, according to Escherich, pupation

Table 24

Incubation period and egg mortality of Bupalus piniarius under different conditions

Temp.	Relative Humidity, Percentage	Incubation period, days	Number Dead	Number Alive	Percentage Mortality
77	100	11	24	1	96
77	93	11	23	2	92
77	44	9	46	79	36.8
71	93	15	2	41	4.7
71	75	14	1	40	2.4
71	43	13	6	27	18.2
70	93	14	1	41	2.4
70	60	13	7	63	10
65	60	17	3	57	5
65	44	16	15	77	15.7
60	100	25	26	26	50
60	75	22	50	54	48.1
56	50	30	8	32	20
50	80	39	60	81	42.5
50	44	34	156	47	69.6

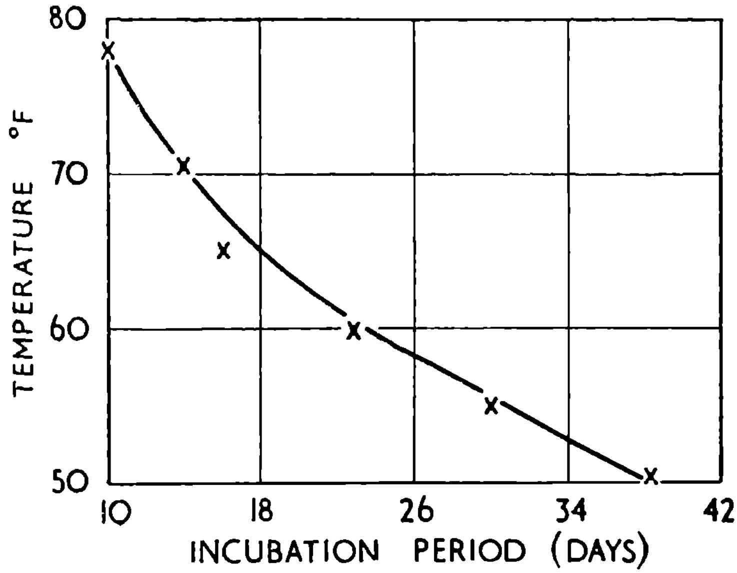


FIG. 4. Incubation period of *Bupalus piniarius* eggs at different constant temperatures.

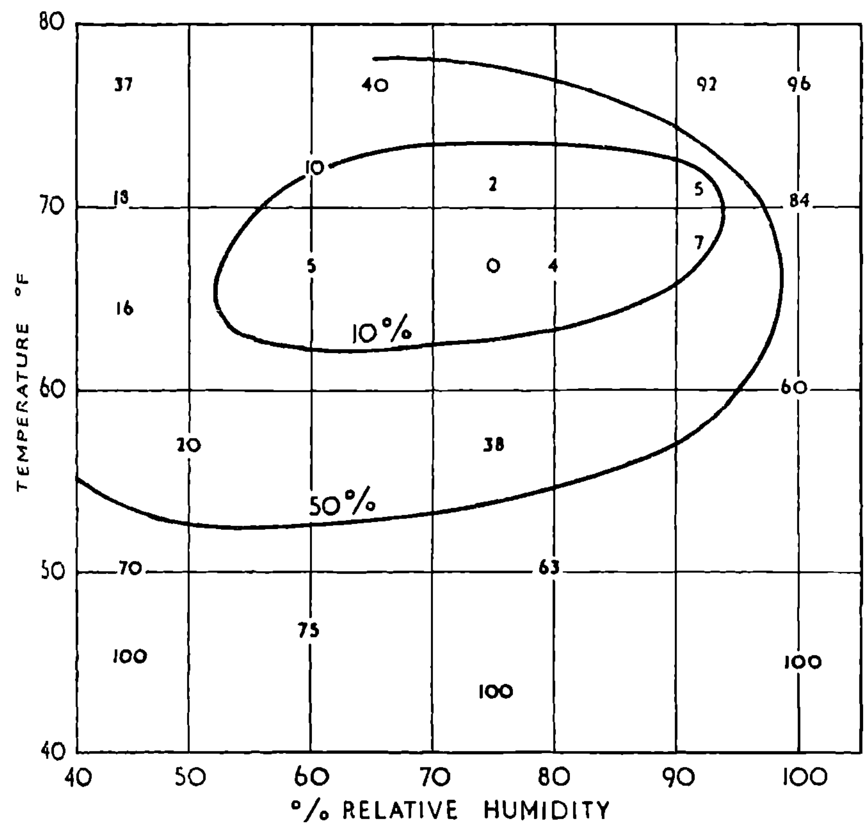


FIG. 5. Mortality of *Bupalus piniarius* eggs at different temperatures and humidities.

may be delayed until the following spring. Until the work of Schwenke (1953), controlled rearing had been neglected. He showed that growth of the early instars was accelerated at higher temperatures, but that the 5th, and sometimes the 4th as well, was prolonged at higher temperatures. He explained this as an adaptation whereby the larvae could utilise the maximum feeding period in those years when adult emergence was particularly early. The following experiments have been conducted to test these hypotheses.

Larvae were reared separately in 2 × 1½ inch tubes maintained at 95 per cent relative humidity, in 2 lb. preserving jars, at various temperatures. Schwenke worked at 75 per cent relative humidity, but it was considered possible that his observations on the delayed growth of the later instars, under such conditions, was due to drying out of the food. In the present study, food was changed every three days and the cultures examined daily for moults. The duration of the instars under a variety of conditions is recorded in Table 25.

Table 25

Mean duration of instars of Bupalus piniarius, in days (with Standard Error of Means)

Temperature, °F	Instar I	II	III	IV	V	Total
77	10 ±0.5	10.4±0.3	9.0±0.5	17.6±2.2	27.9±1.4	74.9
70	12.7±0.3	8.4±0.1	8.1±0.5	11.8±0.7	18.2±1.1	59.2
64	16.0±0.7	11.3±0.4	6.8±0.4	14.7±0.7	20.0±0.9	68.8
50	27.0±0.7	16.1±1.8	43.8±3.1	40.0±1.2	32.5±1.0	159.4
(Alt. 70-50*)	16.0±0.4	10.6±0.1	12.0±0.5	12.5±0.7	21.0±0.9	72.1
(Alt. 64-44*)	20.0±0.4	13.0±0.1	15.0±0.1	24.0±0.4	25.0±0.1	97.0

Note: *Twenty-four hours at each temperature.

The fact that Schwenke failed to get comparable results in successive years, despite using material from the same locality, suggests that the "environmental reaction" of the larvae varies from year to year and probably place to place. In this connection a comparison of the optimal temperatures for each instar, Fig. 6, derived from Table 25 and Schwenke's data, is instructive. The difference in the two curves is probably a reflection of the broad climatic distinctions between the two localities. Larvae of continental origin would be adapted to the longer, warmer summers and cooler autumns.

At most temperatures, Instar III has the shortest stadium, but at 50°F it becomes the longest. Such a drastic reversal suggests that at this stage the larva is particularly sensitive to the amount of warmth.

Table 26 illustrates the striking effect of exposing different instars to different conditions.

There is an obvious retarding effect on the later stadia when the early instars are exposed to temperatures far removed from their optima, even if instars IV and V are subsequently kept under the most suitable growth conditions. The extreme growth retardation at 50°F is very marked, and it is interesting to record that by raising the temperature to 54°F the duration of these later instars may be reduced to only 49 days. These observations suggest that relatively small variations in temperature may cause considerable differences in growth rate. A

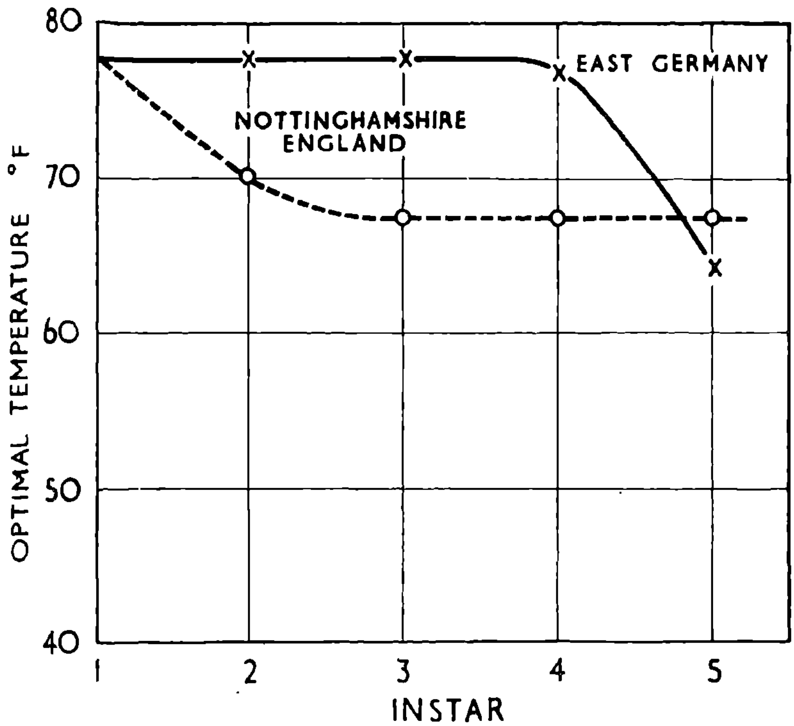


FIG. 6. Comparison between optimal temperatures for larval growth obtained by Schwenke in Germany and figures derived by rearing larvae from Clipstone Forest, Notts. *Bupalus piniarius.*

Table 26

Effect of subjecting larvae of Bupalus piniarius to different temperatures at different stages of growth

Period (in days) of exposure to temperature in column (2) (12 larvae in each test)	Temperature °F	Temperature °F at which maintained for rest larval life	Duration of instars IV and V
30 (i.e. to end of instar III)	70	50	28
30 " " "	70	70	28
86 " " "	50	50	73
86 " " "	50	70	65

possible clue to the reason for these irregularities is evident in the following section.

Relation between feeding and frass production in individual larvae

Schwerdtfeger (1930) carried out a number of experiments to determine the manner in which the assimilation ratio (*Amount of food eaten* divided by the *quantity of frass produced*) altered with larval growth. He presented values of this ratio for larvae of different lengths which, as instars cannot be accurately defined by length, was inconvenient for present purposes.

Rearings were carried out as before, but weighed needles were fed to the larvae. In order to measure the proportion of the subsequent weight loss attributable to wilting, other weighed needles were placed in the test chambers as controls. Each experiment was run for 48 hours when the weight of dried frass produced, and the amount of needle consumed, were recorded. In Table 27 the arithmetic means of the assimilation ratios for each instar were recorded, and from these values the total weight of food assimilated by each instar is calculated in Table 28.

Table 27

Assimilation Ratio of larval instars of Bupalus piniarius at constant temperature

Temp. °F	Instar Number				
	I	II	III	IV	V
77	23.3	5.1	2.5	2.8	1.3
70	24.1	5.7	2.9	1.5	1.4
64	23.8	6.0	3.0	2.2	1.4
50	25.6	11.4	7.0	2.8	1.4

Table 28

Total weights (mgm) of food assimilated by each instar of Bupalus piniarius at constant temperature

Temp. °F	Instar Number					
	I	II	III	IV	V	Total
77	37	39	37	78	84	265
70	29	23	32	28	99	206
64	25	28	23	64	101	247
50	23	21	82	95	118	339

The general tendency of the assimilation ratio to fall with age, follows the pattern found by Schwerdtfeger. Larvae reared at 50°F have a higher assimilation ratio in instars II and III than at higher temperatures, and this may contribute to a higher effective food consumption in instars III and IV. This observation could be interpreted as indicating a disorganisation of the metabolism when early instars experience temperatures removed from the optimum (where optimum is regarded as minimum developmental time). Sattler (1939) found a reduction in the assimilation ratio with increased temperature in *Lymantria monacha*, and Table 27 illustrates a similar tendency.

There is a completely different aspect of the relation between feeding and frass production which assumes importance when the latter is used as an index of feeding intensity. In such observations it is necessary to know the relation in time between the ingestion of a meal and the ejection of frass associated with that particular meal. Rhumbler (1929), using coloured food, concluded that there was a six hour lapse before frass was voided. Gornitz (1933) decided that frass production was coincident with feeding as the gut is always full. To obtain further evidence on this point, larvae were reared separately and watched

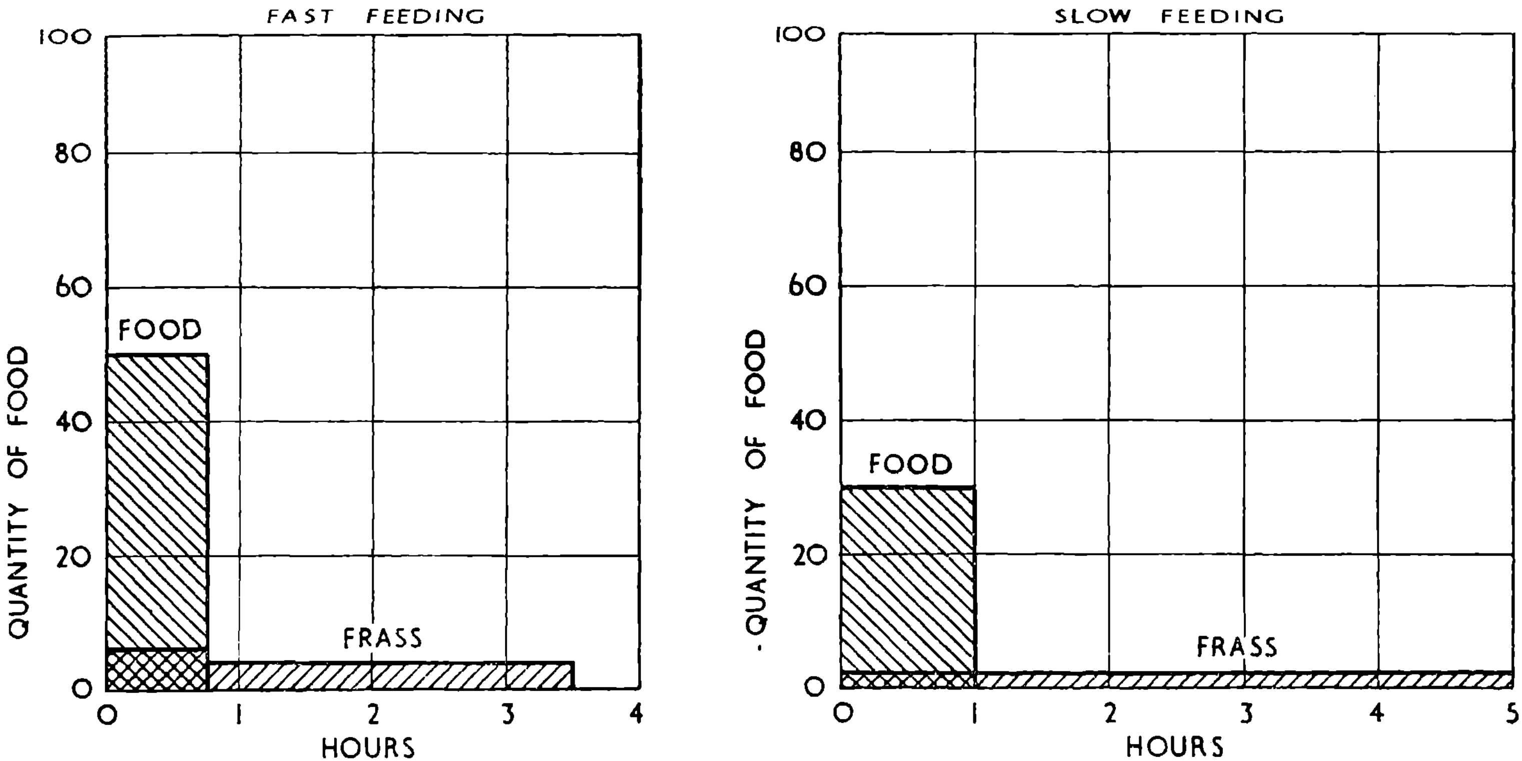


FIG. 7. Relation between feeding and frass deposition in 5th instar larvae of *Bupalus piniarius*. Arbitrary units are used to measure frass and food.

continuously by several observers who recorded the times of feeding and defaecation. It is concluded that the larvae feed several times during the day for about half to one hour at a time, and that defaecation proceeds according to Fig. 7. The same relation holds for all instars and it should be noticed that, although slightly more frass is produced while rapid feeding is in progress, intake of food is reflected by frass production over a period of 3½ to 5 hours.

Effect of Temperature and Humidity on Larval Feeding

In an earlier section, attention has been drawn to the fact that *Bupalus* has a different optimum temperature for each instar. It is not, therefore, surprising to find in the literature several references to the adverse effect of unfavourable weather on larval growth. Eckstein (1923) records that in the cold wet summer of 1912 larval appetite was so reduced that by mid-September the larvae were only ½ cm. long (Instar 2). Borchers and May (1930) and Methner (1929) emphasise that cool, rainy weather severely restricts feeding. Zakharov (1931) showed by frass collections that in cold weather larvae ate 5 to 10 times less than in warmer weather. Schwerdtfeger (1930), also using frass traps, decided that there was no reduction in feeding during raining weather, but lower temperatures do, according to his graphs, have some deleterious effect. Borchers and May also concluded that dew is essential for normal feeding.

Rhumbler (1929) found that the maximum defaecation took place between 19.00 and 01.00 hours, and Frederichs and Steiner (1930) reported that the nocturnal feeding rate was three times that of the diurnal. Gornitz (1933) agreed with these conclusions, but also demonstrated that the time of maximum feeding could be altered by artificial manipulation of the light and dark periods. This peak of feeding in the early hours of darkness has been confirmed in the present investigations, but it was also found that if the mid-day temperatures were sufficiently high (approx. 80°F), the diurnal feeding rate would exceed that of the nocturnal peak. The effect of temperature on feeding by the different instars is similar to that of temperature on growth c.f. Tables 29 and 25.

Table 29

Weight of food (mgm) consumed per day at different constant temperatures by Bupalus piniarius larvae

Temp. °F	Instar Number				
	I	II	III	IV	V
77	3.9	4.6	6.8	6.9	13.0
70	2.0	3.3	6.0	7.2	19.0
64	1.6	3.0	5.0	8.0	17.6
50	0.9	1.4	2.0	3.7	12.7

The early instars have a feeding rate positively correlated with temperature but, as the larvae grow older, high temperatures tend to slow down the feeding rate, presumably because the optimum is lower for those later instars.

Third instar larvae were exposed to a somewhat wider temperature range to emphasise the effect of warmth (Table 30).

Investigation of the effect of humidity on feeding is more difficult, as the variable wilting conditions experienced by the needles may alter their nutritive

Table 30

Defaecation rate of third instar Bupalus piniarius larvae maintained at different constant temperatures for 48 *hours*

Temperature °F	Defaecation Rate per larva in frass granules per hour
73	9.6
60	6.1
47	3.3
41	2.8
39	1.7

value. The method adopted was to pass air of known humidity over the test larvae by means of an electric pump. One group of test chambers received damp air that had passed through water, whilst drier air, after bubbling through sulphuric acid and suitable "baffles" to reduce harmful spray, was passed through the other chambers. The chambers consisted of lantern globes in which corks had been sealed with paraffin wax. Twigs of Scots pine were sealed into the basal corks so that their tips could project into an external vessel of water. The aim was to produce evaporative conditions over the needles similar to those found to occur in the field in earlier work, Hussey (1956). The evaporation rate was measured with the same micro-evaporimeters, of the type designed by Wellington (1949), as were used in the study of microclimate in the field. The air streams therefore gave evaporation rates of 0.14 and 1.67 mm. per minute respectively. The shoots were weighed before exposure in the apparatus and controls maintained, without larvae, to determine the extent of wilting. Each series of experiments lasted 24 hours and was carried out at about 60°F.

Table 31

Effect of Humidity on Feeding Rate in Bupalus piniarius Larvae

Instar No.	Evaporative Rate 0.14 mm/min. (More Humid) Wt. food eaten (mgm) per larva/day	Evaporative Rate 1.67 mm/min. (Less Humid) Wt. food eaten (mgm) per larva/day
II	4.3, 4.6, 4.6, 4.8, 3.9, Mean 4.4±0.3	2.9, 3.0, 3.6, 2.8, 3.2, Mean 3.1±0.1
III	5.1, 5.0, 4.9, 5.8, 5.0, Mean 5.2±0.1	4.0, 4.2, 4.3, 4.7, 4.2, Mean 4.3±0.3
IV	12.6, 10.6, 11.3, 12.3, 11.5, Mean 11.7±0.3	11.3, 10.0, 11.1, 9.4, 11.8, Mean 10.7±1.0
V	11.2, 15.0, 18.4, 19.4, 17.2, Mean 16.2±1.5	17.7, 15.6, 19.2, 17.5, 19.0, Mean 17.8±0.7

It is apparent from Table 31 that young larvae feed more rapidly in humid conditions, but instars IV and V show no preference.

Field Observations on the Feeding Rate

A clockwork-driven aluminium turntable, 2 feet in diameter, was used to record hourly frass samples which, together with thermohygrograph readings, provided data on the feeding rate under a variety of environmental conditions.

The hourly yield of frass was measured by the number of portions of frass trapped by the vaselined surface of each section of the turntable. Fig. 8, derived from these observations over 21 days continuous trapping, illustrates the normal periodicity of feeding. Rhumbler (1929) obtained the highest frass deposits between 19.00 and 24.00 hours, whereas in the present work the heaviest frass fall seems to occur between 23.00 and 04.00 hours. In view of the earlier conclusions on the relation between feeding and frass production, we may assume that the greatest feeding activity occurred between 21.00 and 02.00 hours. The general form of the graph suggests that there are two peaks of feeding activity, the nocturnal one referred to earlier, and a subsidiary between 08.00 and 13.00 hours.

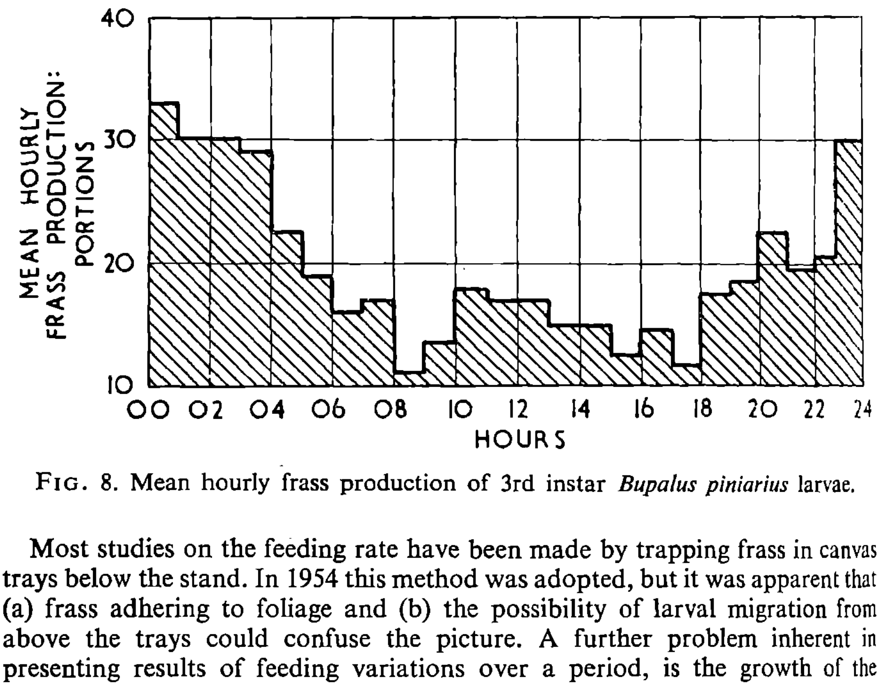


FIG. 8. Mean hourly frass production of 3rd instar *Bupalus piniarius* larvae.

Most studies on the feeding rate have been made by trapping frass in canvas trays below the stand. In 1954 this method was adopted, but it was apparent that (a) frass adhering to foliage and (b) the possibility of larval migration from above the trays could confuse the picture. A further problem inherent in presenting results of feeding variations over a period, is the growth of the larvae themselves, for older larvae naturally produce more frass in unit time. The following conclusions have therefore been based on graphs in which a hypothetical mean frass production has been drawn, so that attention can be focussed on those occasions on which the quantity of frass trapped was significantly different from the average. In Table 32 the "significant" days in the limited 1954 observations are contrasted. The beneficial effect of high temperature, despite rain, on August 5th and 9th is obvious, but on August 6th and 10th rain associated with cooler weather restricted feeding.

In 1955 the technique was modified by observing only a limited number of larvae (36) maintained on a branch of Scots pine liberally ringed with vaseline to prevent larval migration. The significant days are listed in Table 33, in which the theoretical and actual frass yields per larva per day have been compared. The weather, on occasions marked by a depression of the feeding rate, was characterized by the occurrence of rain and cool winds during the period of most intense feeding (i.e. 21.00 to 02.00 hours). The feeding rate may also be severely reduced on clear nights with intense radiational cooling.

Table 32

Quantity of frass trapped below a very heavy Bupalus piniarius population in different weather conditions

Date	Theoretical Frass Yield from graph (mgm)	Actual Quantity Frass trapped (mgm)	Temp. °F (Mean)	Weather
Aug. 5th	56	94	64	Rain a.m.
Aug. 6th	68	34	56	,, ,,
Aug. 9th	98	155	64	,, all day
Aug. 10th	108	56	52	,, p.m. and heavy dew at night

Table 33

Theoretical and Actual frass yields of Bupalus piniarius larvae in 24-hourly periods, from 19.00 hours

Date	Theoretical Frass Yield mgm/ larva/day	Actual Frass Yield mgm/ larva/day	Mean percent. relative humidity	Mean Temp. °F	Weather
Aug. 18	7.2	5.9	74	68	Heavy dew temp. fell to 45°F
,, 21	8.5	7.0	90	62	Rainy at night
,, 23	10.0	13.1	77	69	Misty at night
,, 24	10.3	13.4	75	64	Dew but mild at night
,, 27	12.0	19.2	76	59	Min. night temp. 54°F
,, 30	14.0	9.8	80	64	Rain whole period
,, 31	15.0	22.7	76	58	Heavy dew min. temp. 50°F
Sept. 2	15.5	10.1	75	60	Rain at night
,, 5	16.5	21.5	68	58	Rain after 03.00
,, 10	19.0	12.0	80	58	Cool rain at night
,, 11	19.2	14.2	76	56	Cool wind
,, 12	19.5	7.8	82	56	Heavy showers temp. 56°F for whole period

More feeding occurred on mild, misty nights or when dew formed at temperatures above 50°F, followed, in either case, by warm and sunny days. The contrast between overcast and sunny conditions is illustrated by comparing August 31st, a fine day with clear skies and dew at night when frass was deposited at the rate of 22.7 mgm/day, with Sept. 1st when the feeding rate fell to 14 mgm/day due to the dull weather caused by persistent stratocumulus cloud at a height of 6,000 feet.

In figures 9 and 10 the hourly frass yield, as recorded by the coprometer, have been plotted against the temperature and humidity conditions prevailing some two hours earlier, when the feeding was taking place. These graphs suggest that the larvae react to different optimal conditions nocturnally than diurnally. This is probably an adaptation to ensure the greatest possible food intake in the generally warmer, dry daytime conditions, compared with the cooler more humid weather at night. The pronounced effect of temperature on feeding rate is very marked, whilst the more restricted optimal humidity range by day should be noticed.

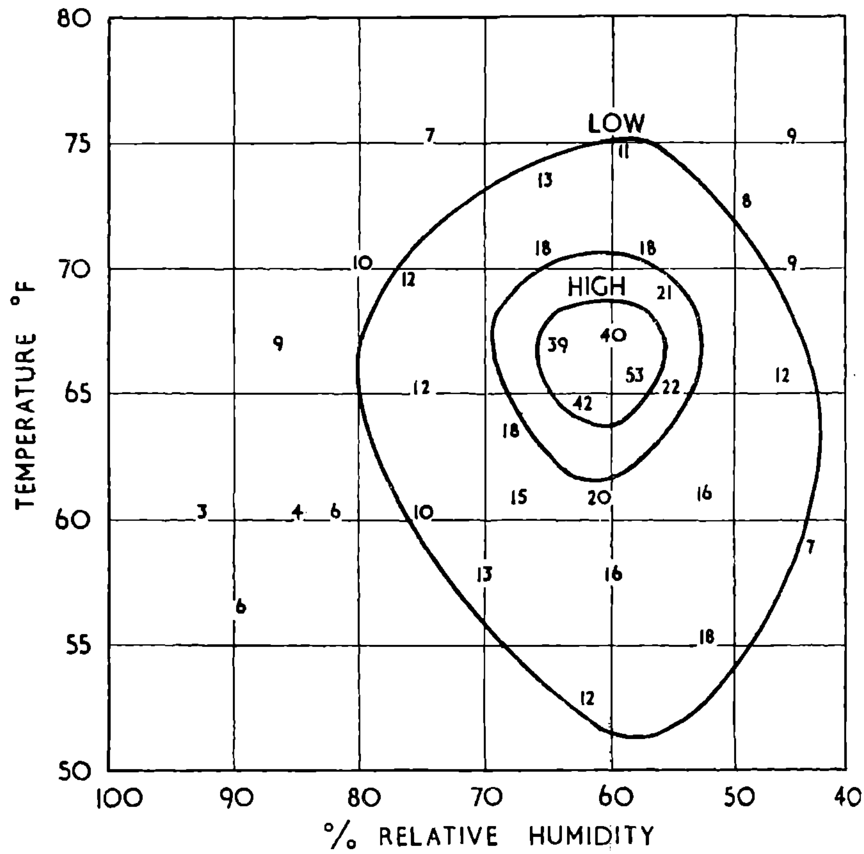


FIG. 9. Hourly frass yield of 4th instar *Bupalus piniarius* larvae in relation to the temperature and humidity conditions at the time of feeding between 10.00 and 16.00 hours.

Major changes in feeding activity only occur therefore in cool wet weather, and on very warm days with dew forming at above average temperatures. Diurnal variations in weather have small but unimportant effects. These conclusions are in general agreement with those of Schwerdtfeger (1952) who states that warm, damp conditions encourage *Bupalus* feeding, whilst hot, dry weather restricts it.

Relation between Larval Growth and Pupal Weight

Schwenke (1953) found that there was a definite tendency for the head capsule width of 2nd instar and older larvae to be smaller at higher temperature, and his results show a similar negative correlation between pupal weight and temperature of larval rearing. The same tendency is evident in the present data (Table 34).

Relation between Pupal Weight and Fecundity

Voelkel (1930) and Schwerdtfeger (1952) both state that when outbreaks of *Bupalus* occur the size and weight of the pupae, and the number of viable eggs laid, increases with successive generations and declines in subsiding epidemics.

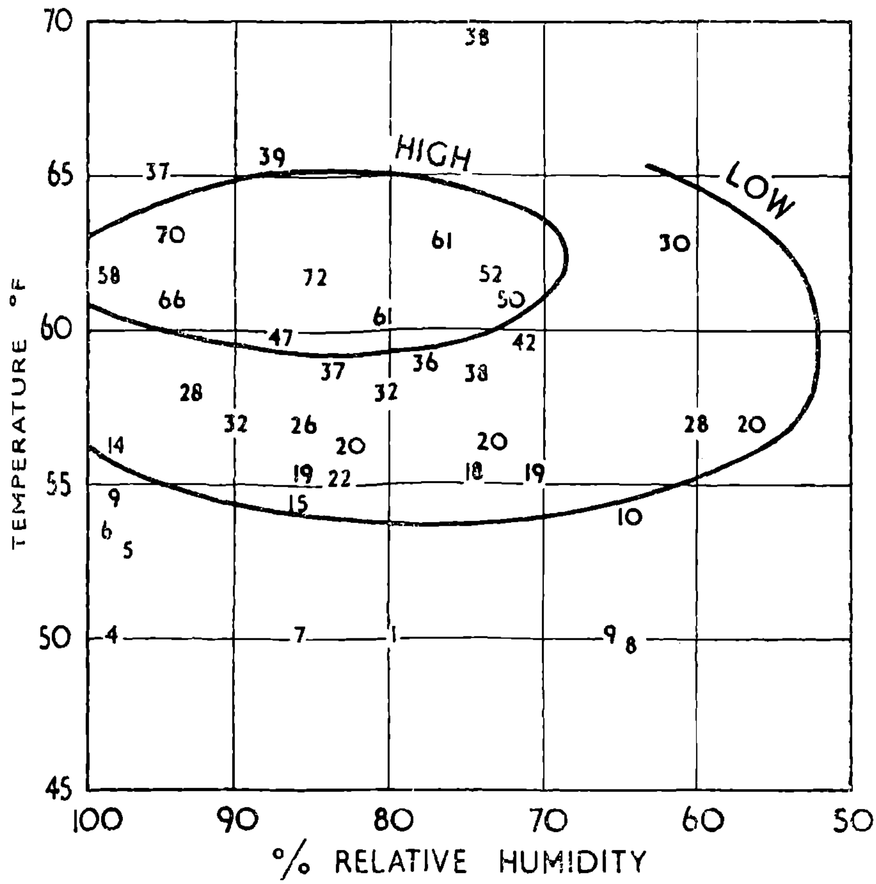


FIG. 10. Hourly frass yield of 4th instar *Bupalus piniarius* larvae in relation to the temperature and humidity conditions at the time of feeding between 23.00 and 04.00 hours.

Schwenke (1953) records that the linear relation is constant only within one generation within one locality. In *Lymantria monacha* he emphasises that genetic degeneration during epidemics can reduce fecundity without affecting pupal weight. Similar relations are given by Brandt (1936).

Females reared from pupae collected at Clipstone Forest, Notts., showed this linear relation, but the inclination of the curve was very different from those obtained by these earlier workers, thereby supporting Schwenke's supposition. It is interesting to record that all the female pupae used in the present study weighed less than all the pupae subsequently reared from them, whatever the environmental conditions to which they were subjected. This observation suggests that such oscillations in pupal weight, associated with expanding or declining populations, are independent of the immediate environment.

Discussion

The hypothesis underlying the present studies was, as developed elsewhere, that optimum conditions for larval growth would result in heavier pupae and therefore higher fecundity in the following generation. It was hoped that it would

Table 34

Head Capsule widths of Bupalus piniarius larvae reared at different temperatures, and their eventual pupal weight

Temp. °F	Head Capsule Width by Instars				Pupal Weight (mgm)	
	I	II	III	IV	Female	Male
77	0.42 ± .006	0.66 ± .016	1.04 ± .021	1.49 ± .055	108.9 ± 3.3	89.0 ± 9.6
70	0.41 ± .006	0.66 ± .073	1.01 ± .017	1.51 ± .03	123.0 ± 10.3	88.3 ± 6.5
64	0.43 ± .006	0.71 ± .016	1.03 ± .01	1.63 ± .006	136.0 ± 6.9	95.0 ± 8.5
Alt. 70-50*	0.40 ± .004	0.69 ± .004	1.09 ± .021	1.56 ± .035	125.6 ± 16.2	87.5 ± 6.3
Alt. 64-44*	0.40 ± .004	0.71 ± .006	1.00 ± .009	1.54 ± .035	122.3 ± 8.0	90.0 ± 4.3
50	0.39 ± .006	0.71 ± .071	1.17 ± .009	1.66 ± .003	135.8 ± 9.5	113.9 ± 7.1

Note: *24 hours at each temperature.

be possible to identify certain environmental factors as limiting to growth. From the data presented, however, it appears that *Bupalus* is well adapted to the wide range of summer weather in the British Isles but that, on occasion, some of the factors may become temporarily limiting.

The adult is capable of surviving several weeks in unsuitable weather until warm, calm days permit oviposition which, like egg hatching, is favoured by temperatures above 62°F and humidities within the range 79-95 per cent. Following the work of Long (1953 and 1955) on the effect of crowding in Lepidopterous larvae, it is important to remember that the number of larvae in close contact in the early stages of growth may influence the total period of development. As few as five larvae in association have been shown to mature in 10 per cent less time than solitary larvae. Therefore, the observation that the number of *Bupalus* eggs per batch decreases under unsuitable environmental conditions, may lead to slower development later, despite apparently suitable weather conditions for more rapid growth. Similarly the deleterious effect of low temperatures on the early instars may lead to unexpectedly slow growth later.

The most important conclusions to be drawn from the present work is that rapid larval development does not lead to heavier pupae than are produced from slower-growing larvae. This result is probably due to the fact that the reduction in feeding and assimilation rates in poor weather is not sufficient to reduce the total quantity of food actually digested.

From the studies of Kozhanckikov (1952) on the effect of the daily range of temperature as a factor of the environment, it may be inferred that large temperature changes suppress growth and disorganise development. As the temperature fluctuations widen, larval weight decreases, whilst mortality and duration of development increase. First instar *Bupalus* larvae, reared at 95 per cent relative humidity, and exposed to a daily range of temperature from 77 to 50°F suffered 100 per cent mortality within 10 days. A lower temperature range between

70 to 50°F still resulted in 30 per cent mortality but the survivors matured as recorded in Table 25. With the same range but at a lower temperature, namely, 64-44°F, mortality rose to 50 per cent. These results suggest that dry anticyclonic weather would be deleterious owing to the wide temperature range from the hot, noon sun to dewfall associated with intense radiational cooling. Warm, humid weather would, therefore, seem most advantageous, and this is further borne out by the observations on feeding rate in the field which was highest on warm, damp nights and warm, but not excessively dry days.

The literature suggests that pupae of Continental origin are considerably heavier than those reared in Britain, possibly because the cooler weather after mid-September tends to prolong the feeding of the fifth instar. Schwenke (1952, 1953) has shown that heavier pupae are also associated with a definite ecological association which he defines on the basis of ground flora as the dry *Fragaria-Vaccinium* (wild strawberry-bilberry) type. These differences of soil moisture may, of course, be merely reflections of other conditions, i.e. topography and air movement, and so could, perhaps, also be correlated with higher needle temperatures.

The most puzzling feature of *Bupalus* development is the wide differences exhibited by material from different localities, and even in different years in the same locality. However, as the cycles of pupal weight are apparently unaffected by immediate environment, it is possible that metabolic changes are under similar cyclic influence. The fact that at least two varieties of the species exist in this country suggests that careful genetical studies will have to be made in the future if these complexities are to be understood.

Deleterious effects of slow larval growth must be sought in variations in disease resistance or metabolic derangement, impeding development of the prepupal phase (Eckstein 1923).

It is, therefore, concluded that the apparent limitation of recurring *Bupalus* epidemics to dry areas must be due to indirect effects of weather on other biotic control factors, rather than to direct effects on *Bupalus* itself.

REFERENCES

BORCHERS, F. and MAY, E., 1930. Erfahrungen bei der Arsenbekämpfung des Kiefernspanners in biologischer und technischer Hinsicht. *Forstwiss. Zbl.* 52.1.

BRANDT, H., 1936. Puppengewicht, Puppengrösse und Eizahl in *Bupalus piniarius* L. *Mitt. Forstwiss.* 7. 413-428.

ECKSTEIN, F., 1923. Zoologisch-meteorologische Studien. Erste Mitteilung: Über den Einfluss von Standort und Klima auf die Gradation des Kiefernspanners. *Z. angew. Ent.* 9. 247-305.

ESCHERICH, K., 1931. *Die Forstinsekten Mitteleuropas.* Vol. III. P. Parey, Berlin.

FREDERICHS, K. and STEINER, P., 1930. Über Nachwirkungen der Begiftung des Kiefernspanners. *Anz. Schädlingsk.* 6.

GORNITZ, K., 1933. Methoden zur Prüfung von Pflanzenschutzmitteln IV. Neue Apparate und Methoden. *Mitt. biol. ZentAnst. Berl.* 46. 1-59.

HUSSEY, N. W., 1955. Some aspects of Pine Looper Outbreaks. *Coedwigwr* 2(3). 77-82.

HUSSEY, N. W., 1956. Bioclimatic Studies on the Pine Looper. *Report on Forest Research*, 1955. p. 80.

KOZHANCKIKOV, I. V., 1952. The question of Vital Thermal Optimums. IX. Temperature Scale as a factor in development of Gypsy Moth and Oak Saturniid. *Ent. Obozr.* 32. 27-42.

LONG, D. B., 1953. Effects of population density on larvae of *Lepidoptera. Trans. R. ent. Soc. Lond.* 104(15). 543-584.

LONG, D. B., 1955. Observations on sub-social behaviour in two spps. of lepidopterous larvae, *Peiris brassicae*, L. and *Plusia gamma* L., *Ibid.* 106(11). 421-437.

MAY, E., 1939. Biological data obtained during control of Pine Moth with Arsenicals. *Verh. dtsch. Ges. angew. Ent.* 8. 38-40.

METHNER, E., 1929. Bekämpfung des Kiefernspanners mittels Flugzeug in Privatforsten des Kreises Lauenburg in Pommern. *Deutscher Forstwirt.*

RHUMBLER, L., 1929. Zur Begiftung des Kiefernspanners (*Bupalus piniarius* L.) in der Oberförsterei Hersfeld-Ost 1926. *Z. angew. Ent.* 15. 137-158.

SATTLER, H., 1939. Die Entwicklung der Nonne, *Lymantria monacha* L., in ihrer Abhängigkeit von der Nahrungsqualität. *Z. angew. Ent.* 25. 543-587.

SCHUCH, K., 1952. Eine Klimatisierungseinrichtung für das Studium ökologischer Fragen bei Holzschädlingen. *Z. Pfl.Krankh.* 59(10). 353.

SCHWENKE, W., 1952. Investigation on fluctuations in numbers of *Bupalus piniarius* L. and *Semiothisa liturata* Cl., on a comparative biocenotic basis. *Beitr. Ent.* 1. 1-55.

SCHWENKE, W., 1953. Beiträge zur Bionomie der Kiefernspanner und *Semiothisa liturata* Cl. auf biozönotischer Grundlage. *Ibid.* 168-206.

SCHWERDTFEGER, F., 1930. Untersuchungen über Dauer des Eistadiums, Wachstum und Stoffwechsel des Kiefernspanners (*Bupalus piniarius* L.). *Z. angew. Ent.* 16. 513-526.

VOELKEL, H., 1930. Vorläufige Mitteilung über den gesetzmässigen Ablauf der Massenvermehrung von Insekten. *Nchr.Bl. dtsch. Pfl.Sch.Dienst, Stuttgart*, 10. 44.

WELLINGTON, W. G., 1949. Effects of temperature and moisture on behaviour of Spruce Budworm. *Sci. Ag.* 29. 201-215.

WÖLFF, M., 1911. Über Biologie und Bekämpfung des Kiefernspanners. *Jber. Ver. angew. Bot.* 9. 82-102.

ZAKHAROV, P., 1931. The experiment of aeroplane dusting in control of *Bupalus piniarius* L. in forests of Central Russian Region and Ukraine. *Bull. Inst. Controlling Pests and Diseases.* 1. 121-126.

ZWOLFER, W., 1931. Studien zur Oekologie und Epidemiologie der Insekten. 1. Die Kieferneule, *Panolis flammea* Schiff. *Z. angew. Ent.* 17(3). 475-562.

SHELTERBELT RESEARCH

By J. NEIL PARKER

Department of Forestry, University of Edinburgh

Introductory 266

The ultimate objective of the shelter research project is the determination of the most suitable sites, species, structures and methods for establishment and maintenance of shelterbelts, so as to ensure maximum sheltering efficiency, particularly in connexion with stockrearing and afforestation on exposed and upland hill areas.

In the first three year period, work was directed towards an examination of the influences exerted by shelterbelts on the micro-climates of adjacent areas, and it included the development of a means of studying the efficiency of shelterbelts through examination of their windfields.

The second phase of the programme was entered a year ago, and it is in part concerned with the practical application of the method of wind study already devised to various aspects of the subject.

Work on the actual design, establishment and treatment of shelterbelts has been augmented. In another direction preliminary work has begun on an informal survey of the present condition of selected shelterbelts in Scotland.

Until July, when Dr. Caborn left the Department, a final collection was made of photographs and other material for publication by the Forestry Commission of Dr. Caborn's thesis. This has now appeared as the Commission's Bulletin No. 29, *Shelterbelts and Microclimate* (H.M.S.O., 1957, 17s. 6d.).

The objectives set up at the initiation of the project have not been strictly adhered to, on two counts.

The application of shelter provision in afforestation has not been touched upon. This is because, although ultimately shelter provision for agricultural land has much in common with that for forest plantations, the initial approach to the two problems is different.

There has also been a tendency to devote less attention to shelter on hill farms than was originally intended, and more to exposed arable and stock-rearing areas at lower elevations. These latter are better provided with the examples of shelterbelts necessary to study.

Instrument Studies

Although the anemometer is the most widely used instrument in shelter research, it is frequently stated that evaporation rate would provide the better index of shelter. To investigate this matter more fully, Dr. Caborn obtained examples of two types of evaporimeter. The first of these is a copy of a Swiss instrument which uses an unglazed ceramic disc as an evaporating surface. The discs used on the original model are wafer-thin, and leading porcelain manufacturers in this country have not been able to make a comparable product. The discs obtained are several times thicker, and due possibly to their rigidity a seal cannot be maintained between porcelain and ground glass, and the water escapes.

The Piche evaporimeters employ a small disc of filter paper as an evaporating surface. These have been tested over a period of six weeks and some of their limitations discovered. The paper disc is rather delicate as it is permanently saturated with water. Consequently in high winds it frequently ruptures, and it disintegrates in heavy rain. In light rain, water is drawn back into the reservoir to a degree which varies with the instrument, and an inverted reading is obtained.

There appear to be two main defects in the design of the apparatus; the discs, which probably vary slightly in their properties, must be changed at the end of each run; there is no way of ensuring that the clip which holds the disc in place, over the mouth of the tube applies the same pressure in each case, or that the pressure is exerted in precisely the same plane as the end of the tube.

The tests have shown very little consistency in the behaviour of the Piche evaporimeters, but with more experience it may be possible to use them under conditions of light wind to study climatic factors.

Wind velocity is the factor which governs the exposure complex, and it is relatively simple to study. Hence the original model of anemometer, supplied by Messrs. Casella, Ltd., remains the principal instrument for microclimatic studies.

There has been a lapse in the number of wind studies during the past year, due partly to the need for the new staff to become familiar with the technique, while the later winter and early spring months were exceptionally calm. However, several experimental wind profiles were made, and this experience has enabled the procedure to be refined and speeded up. To this end, one new anemometer has been obtained and two more are on order. This will bring the total to nine and cut the time required for a typical wind profile measurement by one third, thus reducing inaccuracies due to wind variation. In addition, a standard procedure is being evolved which it is hoped will make direct comparison of profiles simple.

Various aspects of the shelter problem will be investigated by this technique. Shelterbelts having varying proportions of leaf-trees have been selected for measurement under winter and summer conditions. Another comparative series of studies which is proposed, concerns belt structure before and after cultural operations.

A long-term series of investigations is anticipated in tracing the development of a number of belts from their early stages.

In the first phase of the project great care was exercised in selecting belts for study, particular regard being given to local topography. Measurements were made only where the land on both sides of the belt was open and flat for long distances. It is now intended that work should include a consideration of the effect of local topography on wind movement, as in fact belts are rarely situated on flat ground. It is also necessary to learn more about the optimum siting of belts in broken country. To this end, profiles may be prepared for stretches of broken country without belts.

Wear of Fabrics as a Measure of Exposure

A minor project has been the investigation of the possibilities of unhemmed flags for comparing exposure, and perhaps for assisting in siting new belts.

Work to date has been expended only in attempts to devise satisfactory flag-mounts, and to discover suitable fabrics. Tests have been in progress throughout the year on the roof of the Department. The roof is very exposed, and the eddies caused by superstructures provide a thorough test for flags and mountings.

The essentials of a good mount are that the flag must always be in a position to fly freely, and that there should be no chafing of the flag against the mount.

It was assumed at the start that a flag hanging like a banner, and flying in a horizontal plane, would lift more easily, and be less likely to come into contact with its supports than a conventional flag. Using a single flag in this manner would necessitate having a large framework superimposed on a swivel head. For this reason, a unit carrying two flags at the extremities of a horizontal cross piece was built. A vane was necessary to hold the device steady and it was thus rendered very cumbersome. Moreover, several methods of attaching the flags were devised, but none succeeded in preventing the flags from fouling their supports. The idea was eventually abandoned as five or six bearings would have to be fitted to overcome this difficulty.

The second device was a simple vertical flag attached to a staff and rotating on a point bearing and in a ball-race. This has proved more successful, but not wholly so, as it is possible for the flag to come into a position where it is held against the staff by the wind so that there is the same amount of drag on each side and no tendency for the flag to unroll.

In the next instance, the flag was attached to the trailing edge of a vane. Due to its weight and large surface, this unit would not remain steady in a fluctuating wind, and frequently made several complete revolutions. However, it led to the latest design, which consists of a vertical light wire frame on a pivot. It is balanced both aerodynamically and by weight, and the flag is attached to one edge. This has been on test for two weeks, and the flag has flown steadily without fouling for this period.

Six widely differing fabrics have so far been tested, and none have been found to be completely satisfactory. The aircraft material Madapolam has less disadvantages than the others, but it is extremely durable and will withstand many months of severe exposure. Fibre-glass abrades rapidly, but felts badly and produces loose threads which tangle round themselves and the supports. It is also relatively heavy.

Linen scrim and wool bunting both fly extremely well, even when wet, but they are very durable and lose weight mainly by the loss of complete lengths of yarn. After several days, this stops almost completely. One material made up from synthetic fibres showed no signs of deterioration following several weeks of exposure.

The most recent material to be tested is butter muslin. Apart from a tendency for loose threads to tangle, it seems to fulfil the purpose quite well. However, the quality does not appear to be sufficiently uniform.

Eighteen flags of butter muslin on the roller-type mounts have now been out in the field for two months. They are arranged to traverse prominent ridges on two situations. A superficial examination reveals more tattering on the most exposed flags, but more accurate information will be obtained by ascertaining loss of weight.

The qualities which are required in a fabric for this purpose are now well appreciated, and this will help to direct the search for other materials.

Silviculture and Management of Shelterbelts

This section of the project is being expanded, and examples of several of the existing problems in this field are now represented in work being undertaken. New belts are being established on pasture and arable land and disintegrated ones are being re-established; trials are being made in the rehabilitation of derelict belts and the rejuvenation of moribund ones; some of the belts are undergoing fairly normal cultural operations, whilst others are being converted from even-aged stands of unsuitable species to belts of more useful structure and composition.

This year's work has included the planting of experimental belts at the Langhill and Easter Bush, Midlothian, farms of the Edinburgh Centre of Rural Economy. Use has been made of a high proportion of leaf-trees mixed by groups, and several species of shrub not normally employed for shelter work have been included in the margins. At Boghall, Midlothian, the experimental conversion of a failing Sitka spruce belt to an uneven-aged mixture of species is continuing.

In addition to these enterprises the co-operation of several private landowners has been secured, and two management plans for shelter systems have been prepared.

Drumbeg Farm is owned by Dr. John A. Watt, and lying in West Lothian on the highest part of the Forth-Clyde divide, is severely exposed. The farm includes arable land and rough and improved grazing. Both of these are suffering from lack of shelter once provided by a system of shelterbelts. This system is now almost completely disintegrated and the plan which has gone into operation this year provides for the formation of new belts and the rehabilitation of old ones.

The second management plan, which is also going into effect this year is for the Cockburn and Cockdurno Farms, properties of Sir A. D. Buchanan-Smith. These two farms are situated in Midlothian about twelve miles south-west of Edinburgh and are managed as one unit for milk production and stock raising. That they perform these functions so effectively under the prevailing conditions is largely due to a well planned shelter system of about fifty acres. This was originally laid down in the first half of the nineteenth century, probably with beech, sycamore and pine as the principal species. Extensive plantings were made early in the present century in an attempt to repair the neglect which the original belts had suffered. These plantings were almost entirely of conifers, and the stands, having been neglected since their establishment, are in a critical condition.

The plan introduces an attempt to secure a more normal distribution of growing stock and a more suitable balance of species. This will be begun by increasing the stability of the coniferous belts by thinning, and incorporating the remnants of the original stock into planting schemes.

The preparation of plans for shelter systems is necessarily experimental, but the plans have been written on fairly orthodox lines with provision for the incorporation of formal experiments.

At Braidwood, Midlothian, a stock-raising farm on the southern slopes of the Pentland range, a small belt was planted last year as an addition to the several which already exist there. The owner, Mr. D. H. Macalister-Hall, has expressed a desire to have the shelter improved, and a management plan is in the course of preparation.

The belts are of two broad types frequently found in the Lothians. The first derive from the work of the original improvers of the last century. They are sparse stands of large beech with some remaining sycamore and Scots pine. The remaining shelter on the farm is in the form of short belts and blocks of dense conifer poles. Sitka spruce predominates and as signs of failure are appearing, it will be necessary to devise a system of gradual replacement.

Other landowners who are interested in preserving or providing shelter for their land have been contacted, and it is hoped that co-operation between them and this Department will develop.

In connexion with this work, and to assist and encourage landowners to take up plans for their shelter systems, the stocks of seed and plants which have been built up under the project are being increased. Preference is being given to hedging and "edging" species which are not readily or economically available through the trade, and to certain rather unusual trees also not in common use.

Survey of Shelterbelts

This study is on a long-term basis. It is thought that in future there may be a widespread renewal of interest in shelter, and it would then be useful to have information available showing the overall position with regard to shelter in Scotland.

The survey will also draw attention to the need for rehabilitation of derelict and moribund belts which exist in high proportions at present. In developing the technique to be employed, consideration has been given to devising a classification of belts based to a large degree on the features which would govern their subsequent treatment.

The first step was taken in December 1956, following the appointment of Mr. Murray to the staff. This was to draw up a concise method of recording the salient features of belts, their structure, function, situation, etc.

This prototype descriptive form was applied to some forty belts in the Edinburgh area and revised in the light of experience gained. Areas on the Ordnance Survey Popular Edition one-inch sheets showing concentrations of shelterbelts were visited, and as many as possible of the belts were described using the revised form. No discrimination as to condition, effectiveness, etc., was exercised in selecting belts for description.

Approximately 100 belts in the Lothians have now been described, and further work includes the drafting of the final form, coupled with classification of belt types based on information obtained from the descriptions.

The next stage will be sampling, description and classification of belts in Midlothian, perhaps followed by an extension of the survey to other Scottish counties.

In addition to its primary functions, the survey work provides material for study under other sections of the project. Belts of which wind-studies are desirable are revealed; and it is hoped to collect information on the reaction of individual tree species to exposure, and evaluate their general suitability for shelter work.

GREY SQUIRRELS

By Mrs. M. R. VIZOSO

Infestation Control Division, Ministry of Agriculture, Fisheries and Food

451.2

Work on the problems connected with the control of grey squirrels has continued, in collaboration with the Ministry of Agriculture, Fisheries and Food. Mr. P. Pearce has been assisting Mr. F. Courtier at Alice Holt.

Survey of Damage

Damage caused to main stems of trees by squirrels on Commission areas in England, Scotland and Wales has been surveyed each year since 1954. During Forest Year 1956 reports were received from 551 forest areas; 229 of which reported grey squirrels to be present, and 271 of which reported red squirrels as present.

Damage was caused by grey squirrels on 45 areas; only one case of severe damage (at Tintern, Monmouth) was listed. (In 1955, 68 out of 538 areas suffered damage, and in 1954, 87 out of 469). Rather surprisingly, 122 out of 140 reports on the relative abundance of grey squirrels in 1956, as compared with the previous year, stated that there were less squirrels present. General observations from other sources suggested that grey squirrels were scarce throughout the country in 1955; but that after the spring breeding in 1956 they increased in numbers, and have continued to increase up to the summer of 1957.

The frequency of attacks on various tree species by grey squirrels were as follows: sycamore, 22 areas; beech, 21 areas; birch, 4 areas; Scots pine, 4 areas; oak and ash, 3 areas; elm, 2 areas, and maple, alder, hazel and Japanese larch, one area each. The three instances of damage to oak again came from the southwest. Scots pine was attacked on three areas where red squirrels were absent, and on one where they were present but scarce.

Red squirrels caused damage on 13 forest areas, in two of which damage was said to be severe. Scots pine of 20 to 40 years was most frequently attacked.

The questionnaire forms were filled in by the forester in charge of each forest unit.

Distribution of Squirrels

Records have not shown any marked increase in the range of the grey squirrel during the period from March 1956 to March 1957. Table 35, based on the questionnaire returns sent in by foresters, appears to reflect some interesting correlations between presence or absence of red squirrels in forest units and the length of time during which grey squirrels have been known to have lived in the neighbourhood.

Table 35

Presence of Grey and Red Squirrels, 1956-57

	Forests with red squirrels	Forests without red squirrels	Total	Percentage of forests with red squirrels
Grey squirrels present in area since before 1935	3	70	73	4
Grey squirrels present in area by 1945	21	43	64	33
Grey squirrels present in area by 1955	58	19	77	75
No grey squirrels in area	66	28	94	70
Total	148	160	308	48

Population Studies

Grey squirrels living on a small area have been live-trapped and marked at intervals of six weeks since June 1954. Whereas in the spring of 1955 these animals did not breed, and in the following summer only two females were found to be pregnant, in 1956 and 1957 normal breeding occurred. June is the month when greatest numbers are trapped; in 1954, 1955 and 1956 the totals were: 39, 18 and 35; 7 of those taken in 1956 were survivors from 1954; 8 had been trapped first in 1955 as adults or yearlings; the remaining 20 (13 of which had been born in spring 1956) were taken for the first time in June 1956. In September 1956 natural food was so plentiful that no captures were made during four days of trapping; this was the first time that this had happened since the start of the experiment. This work provides an opportunity to study length of life, breeding rates, and movements under natural conditions.

Four hundred and thirteen grey squirrels killed at Westonbirt, Glos., in spring 1957 were examined to allow an estimate of the breeding rate during that season. A steady gradation in uncleaned bodyweight and in development of permanent dentition suggested that there had been no clear break in breeding since the autumn of 1956. Of 158 females weighing over 450 grams, only 64 had not bred during that time, and 52 of these were virgins weighing 550 grams or less. The average number of young per female (from a count of placental scars) was 3.5, ranging from 1-8. This may be compared with an average of 2.90 (range 1 to 6) for 42 breeding females examined from Adhurst, Hants., in the spring of 1954. Unfortunately there are no previous observations for the Westonbirt area.

The conclusions drawn from these studies are that numbers have built up again after the decline in 1955, as a result of greater breeding activity. General observations suggest that this applies over most of the country.

Control: Trials of Traps

The performance of the Young trap, a single-catch cage type manufactured by Nash and Morgan, has been compared with that of the single-catch Legg cage-trap in two further tests. Scarcity of squirrels and difficulty in selecting comparable sites for all traps made statistical analysis of the results inconclusive. Familiarity with both designs during more than a year's field work has led to the conclusion that they are equally effective against grey squirrels.

A new design of trap, known as the Fuller, was tested for effectiveness. It is designed to kill squirrels, by means of a spring housed in a metal box, which comes into action when a squirrel depresses a trigger pan, set inside the trap, at the back. It was found to be humane, safe for other species if simple precautions were taken, simple to set and site, and compact and easy to carry. Seven traps killed 18 squirrels in 4 days.

Comparative trials of the Imbra mark 1, the Imbra mark 2, and the Fenn trap were made on two occasions; firstly in December 1956 when a dozen traps of each type were set in tunnels and operated for fourteen days. Results showed no significant differences in efficiency between the three types. Results are given in Table 36.

The results of the second trial, in April 1956, confirmed these results, but it was found that the Imbra I did not kill as quickly as did the other types.

During a visit to Thetford Chase, tests were made on the performance of the Legg single- and multiple-catch traps, and the Young trap, against red squirrels. All were found to be effective. Acorns were shown to be an attractive bait. An assessment of damage caused to young Scots pine on the area revealed a total of 186 out of 1,664 trees to have been damaged in May 1956.

Instructional and Other Work

A short film is being made, in colour, to illustrate the work being done on various aspects of squirrel research.

Table 36

Results of Tests on Imbra and Fenn Traps, Forest of Dean

Trap type	Squirrel dead	Squirrel alive	Thrown		Totals	
			By squirrels	By other means	Squirrel captures	Thrown, no capture
Imbra 1	13	1	6	3	14	9
Imbra 2	6	1	2	3	7	5
Fenn	6	3	7	0	9	7
Total	25	5	15	6	30	21

As in previous years a Grey Squirrel Exhibit has been displayed at the main Agricultural Shows, and Mr. Courtier has arranged several demonstrations of trapping methods as well as dealing with a large number of outside enquiries on matters relating to both red and grey squirrels.

PART III

Reports on results of Individual Investigations

METHODS USED TO CONSTRUCT THE REVISED YIELD TABLES FOR CONIFERS IN GREAT BRITAIN

By F. C. HUMMEL and J. M. CHRISTIE

566

The following note outlines the methods used in the construction of the revised yield tables for conifers in Great Britain (Hummel and Christie 1953) and briefly discusses some of the more important relationships used. The methods will be discussed more fully in the proposed bulletin on the growth and yield of conifers, the preparation of which has been unavoidably delayed. This note is published as an interim measure because of the interest shown in the methods used.

(1) The yield tables were prepared entirely from permanent sample plot data.

(2) The procedure used in their construction was essentially empirical and subjective and it was derived from, but was not identical with, methods previously used in this country and elsewhere.

(3) Considerable use was made of two observed facts:

(a) Total volume production per acre is closely correlated with the top height of a stand, and the total volume production reached at a given top height is not influenced appreciably by the rate of height growth, i.e. by the number of years required to reach that height. For example, quality class I Sitka spruce takes 27 years to reach a top height of 50 feet, and quality class V takes 50 years; but both crops at that height will have produced a total volume of about 6,700 Hoppus feet per acre over bark. There was some indication that, while this close correlation between total volume production and top height irrespective of the rate of height growth held good within a region, it varied from region to region for reasons not yet understood; but the amount of variation was not enough to warrant the preparation of separate yield tables for each region.

(b) Volume and basal area increment per acre is similar within a wide range of thinning treatments. This does not necessarily mean that thinning treatment has no effect on volume increment; it appears more likely that thinnings stimulate volume increment in some ways and retard it in others. That would explain exceptions to the general rule on certain sites where the opposing influences may not balance. For example, thinnings influence the soil temperature and the amount of light and moisture that reach the forest floor, and also the amount and type of ground vegetation.

(4) The differentiation of quality classes was based on the top height of the crop at the age of 50 years, and a difference of 10 feet in top height at this age was chosen as the interval between adjacent quality classes. The sheaf of quality class curves was drawn in the conventional way, the mean line for each quality class following the trend of the data.

(5) The quality class of each sample plot was then determined; if the quality class of a plot had changed since the first measurement the quality class at the most recent measurement was taken.

(6) The various crop characters were plotted against top height, the data for each quality class being plotted on a separate graph. The characters concerned were: total crop volume and basal area (total crop being the standing crop plus all thinnings to date), standing crop volume and basal area, number of stems per acre, standing crop form factor, and mean girth. In addition, standing crop form factor and number of stems were also plotted over mean girth. On each graph, the different thinning treatments were distinguished by colours; the points relating to successive measurements in a plot were connected by straight lines.

(7) These graphs were studied to see whether the relationship of the various crop characters on top height varied between (a) quality classes and (b) thinning treatments.

(a) QUALITY CLASSES. The evidence on this point was not conclusive. In some cases no differences at all were observed, in others, the data suggested that there may be slight differences; for example it appeared in some species that the total crop volume at a given top height was greater where the rate of height growth had been slow, than where it had been fast. But even if these differences between quality classes are genuine and not due to chance, they are small compared with the differences between plots of the same quality class; differences which must be due to other causes either not known, or if known, of a kind that cannot be taken into account in the preparation of a general yield table. It was decided, therefore, to accept for each crop character, a common relationship for all quality classes.

(b) THINNING TREATMENTS. The second object of plotting these various crop characters over top height was to discover the effect of different thinning treatments on these relationships. The relationships of total crop volume and basal area over top height were found to be the same for all thinning treatments. Thinning treatments usually have little effect on height growth, but where, in a series of adjacent sample plots of the same species which had been established to compare the effect of different thinning treatments, one of the plots was slightly taller than the rest, the total volume production was also correspondingly higher.

(8) From the above observations it was decided to construct first a so-called "master table" for each species. This is a yield table based on top height alone, and is applicable to all quality classes. The "master table" for Sitka spruce is given as an example in Table 37. The construction of a "master table" is only possible if there are no significant differences between quality classes in the relationship of each crop character with top height, so that a single line drawn through the data will fit all quality classes.

Table 37

"Master Table" for Sitka Spruce

Over-bark

100 largest trees per acre		MAIN CROP						THINNINGS			Total Crop Yield to date	Volume Increment per one ft. of Height Growth. Hoppus ft. per acre
Average Height (feet)	Av. Quarter Girth at Breast Height (inches)	No. of stems per acre	Average Height (feet)	Av. Quarter Girth at Breast Height (inches)	Basal Area per acre (Hoppus square ft.)	Form Factor	Volume Hoppus ft. per acre	No. of stems per acre	Av. Quarter Girth at Breast Height (inches)	Volume Hoppus ft. per acre	Volume Hoppus ft. per acre	
30	4¾	1,300	27	3¼	102	.36	1,000	400	2¾	160	1,160	
												115
40	5¾	900	36	4¼	114	.43	1,770	400	3¼	380	2,310	
												137
50	7	610	46	5¼	122	.45	2,550	290	4	590	3,680	
												149
60	8¼	430	56	6½	128	.47	3,340	180	5	700	5,170	
												154
70	9½	315	66	7¾	133	.47	4,140	115	5¾	740	6,710	
												157
80	10¾	240	76	9	137	.47	4,930	75	6¾	780	8,280	
												158
90	11¾	188	86	10¼	140	.47	5,700	52	8	810	9,860	
												160
100	12¾	152	96½	11¾	144	.47	6,460	36	9¼	840	11,460	
												162
110	13¾	125	107	13	146	.46	7,200	27	10½	880	13,080	

(9) The relationship of each character on top height was determined by eye. In the relationships of total crop volume, total crop basal area, and form factor, on top height, all the data were included, as these characters are not appreciably affected by thinning treatment. In other relationships, e.g. number of stems per acre and mean girth over top height, only those plots were included in which the thinning treatment approximated to the treatment assumed in the yield table. For the larches a heavy low thinning (D grade) was assumed, while for the other five species, the thinning grade was a moderately heavy low thinning (C/D grade).

(10) To construct the master table, the values of each crop character were recorded from the mean lines on the graph. Height intervals of ten feet were used in these tabulations for all species except Norway spruce, where the intervals were five feet. The values of the various characters are not mutually independent; for example, the basal area per acre, multiplied by the form factor and mean height, must equal the volume per acre shown; the basal area corresponding to the mean breast-height quarter-girth, multiplied by the number of stems per acre, must equal the basal area per acre. As an additional check, the average volumes per tree were compared with those given in the published general volume tables for conifers.

(11) From the height-over-age curves and the "master table", yield tables of the conventional type were constructed. In these yield tables the age and height intervals were chosen to agree as closely as possible with thinning intervals occurring in practice. The interval was three years in the early stages, extending to five or even ten years as the crop grew older. As described in paragraph (10), the various crop characters are not mutually independent, and therefore there had to be, as in the "master table", some "harmonising" of the data.

(12) This method of constructing the yield tables, assuming a single relationship between the various crop characters irrespective of quality class, enabled alignment charts for the estimation of standing volume per acre to be prepared for each species. The construction of these involved the further assumption that, for a given height, the form factor of the crop does not vary with stocking. The alignment chart for Sitka spruce is given as an example in Figure 11. In order to determine the standing volume from it, a ruler is placed across the chart linking the top height and basal area per acre of the crop; the estimated volume per acre is then read from the volume scale on the right of the chart, at the point at which the ruler intersects it. For example, if the top height of a crop of Sitka spruce is 44 feet, and the basal area per acre 96 square feet, the estimated volume read from the chart is 1,660 hoppus feet.

REFERENCE

HUMMEL, F. C. and CHRISTIE, J., 1953—*Revised Yield Tables for Conifers in Great Britain*. Forestry Commission Forest Record No. 24. H.M.S.O.

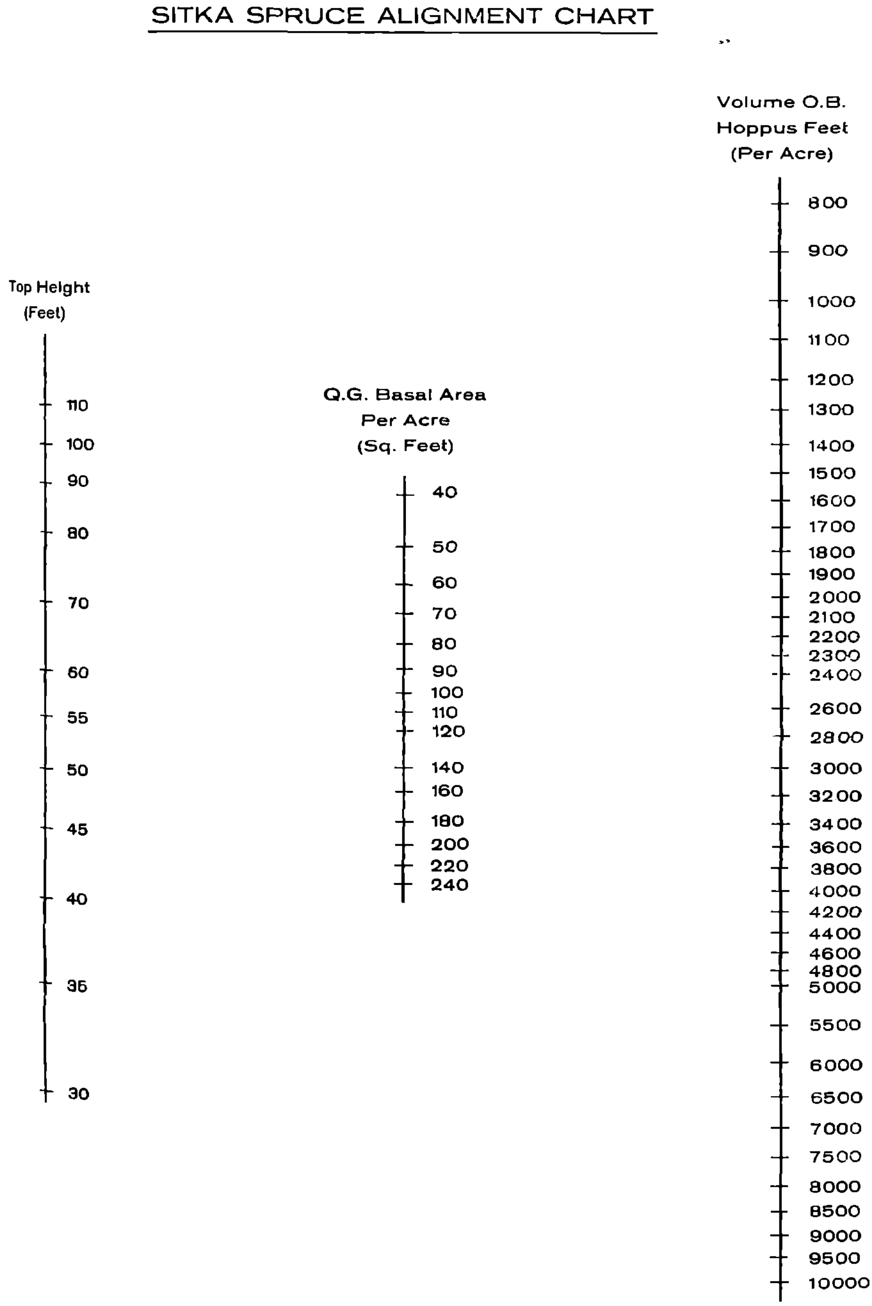


FIG. 11. Alignment Chart for Sitka spruce, to give the volume per acre when the basal area per acre and top height are known.

results, if the seeds are immersed in the tetrazolium solution for a long enough period; the more fully the embryo was exposed in preparing the seeds, the more rapidly was the staining reaction completed.

The reaction time required ranged from 3 to 70 hours immersion, according to the preparation applied. The aim, of course, was to work out the quickest and most convenient method of seed preparation, which gives a reasonably short reaction time when immersed in tetrazolium solution. Complete excision of the embryos before immersion gave the shortest reaction time, but the preparation was time-consuming owing to the care needed in extracting the embryos without damage. Immersion of chipped seeds, or seeds with testas removed, required prolonged reaction times of the order 20 to 40 hours, compared with about 3 hours for completion of staining with longitudinally cut seeds. In the latter technique, which was finally adopted as the most suitable for conifer species, the seed is cut longitudinally, slightly off-centre, so that part of the embryo, and a large part of the endosperm, are exposed during the reaction with tetrazolium. In practice, it is difficult to avoid cutting off a small portion of the embryo, particularly when handling very small seeds. However, this does not appear to interfere with the staining process, and in cases where the embryo has been cut, the undamaged surfaces are examined for the distribution of staining.

The standard procedure of work now employed for routine tetrazolium tests is as follows:

(1) Soak the seeds in tap water overnight.
(2) Cut seeds longitudinally slightly off centre.
(3) Immerse cut seeds in 1 per cent tetrazolium bromide and place in an incubator for 3 hours, in darkness at 30°C.
(4) Drain off, and wash out, excess solution with water, using two changes of water.
(5) If embryos cannot be examined within two hours of completion of staining, immerse seeds in 20 per cent formaldehyde for 15 minutes.
(6) Extract the embryos from the cut seeds.
(7) Classification of embryo staining categories.

A most difficult problem in this work was to define a reliable and objective scheme for classification of embryo staining categories for estimation of seed viability. In all the routine tetrazolium test work reported here, the following embryo staining categories are interpreted and recorded as viable seeds:

Category "A"—Embryos coloured over the entire surface.

Category "B"—Embryos with unstained parts less than 1/6th of the total surface area.

All embryos completely unstained, or with unstained parts exceeding 1/6th of the surface area, are regarded as non-germinable.

Classification on this simple arbitrary system is quick and objective, and using the procedure outlined, an experienced analyst can complete up to three tests per day when 3 × 100 seeds per test are used. Speed is the great advantage of the biochemical test, and the fact that a test can be completed within 24 hours can be of immense practical value under many circumstances. However, it is interesting to note, that in terms of actual working time, or "man-hours" per test, the requirements of the tetrazolium test and a standard laboratory germinator test, are approximately the same.

Shortly after the above method of classification based on *embryo* staining was adopted, Lakon (1950), published his paper in which he advocated the inclusion of *endosperm* staining in the classification scheme. Consequently a series of tests was carried out on Scots pine, Douglas fir and Sitka spruce to examine the significance of endosperm staining on a set of seed samples for which the results of embryo staining gave a poor estimate of actual germination value. The tests, however, gave no clear indication of the way in which assessments of endosperm staining could be used to add to the accuracy of estimates. Maybe the experiment was carried out on unsuitable material, but the samples examined were deliberately chosen as examples for which the embryo staining technique had proved inaccurate. For most *Abies* species, the embryo staining method was not very satisfactory, viability estimates based on staining categories "A + B" resulting in significant over-estimates of actual germination value. Because of this, all tetrazolium tests with *Abies* species during 1957 have included classification by embryo *and* endosperm staining to provide data which may assist more accurate viability estimates. For all other species, the tests reported relate entirely to the embryo staining method.

Analysis of the Results of Routine Tests

During the period 1949 to 1957, 766 tetrazolium tests were completed on samples representing 487 separate homogeneous seed lots. For all these tests the procedure was to check the results of tetrazolium tests by standard germinator methods, so that a large volume of comparative data is now available, which can be used to examine the accuracy of the tetrazolium estimates in relation to the results of approved germinator methods.

Several of the 487 seed lots examined were large enough to be represented by more than one sample for analysis, which explains why the number of tests completed exceeded the number of seed lots examined. For purposes of statistical analysis, the main interest lies in comparisons between different seed lots. Consequently, in those cases where more than one test was made on the same seed lot, the results were averaged for each lot, so that all seed lots were given the same weight in computing regressions, etc. The following table lists the numbers of seed lots sampled, and the number of tests completed, by species:—

Table 38

Numbers of Seed Lots sampled for which Tetrazolium Tests were Completed in Routine Analyses during period 1949-57

Species	Number of Seed Lots	Total Number of Tests Completed
Scots pine	101	117
Corsican pine	12	34
Lodgepole pine	37	42
European larch	42	46
Japanese larch	32	97
Norway spruce	21	27
Sitka spruce	47	95
Douglas fir	75	119
Western hemlock	24	31
Grand fir	26	61
,, ,, ...	8	14*
Noble fir	50	69
,, ,, ...	12	14*
Total	487	766

Note: **Abies* species for which *endosperm* and embryo staining was assessed.

As stated, all the above tests were checked by a standard germination test on filter paper in Copenhagen tank germinators as follows:

Scots pine, Corsican pine, European larch and Norway spruce	21 days at 20-30°C.
Noble fir and Grand fir	28 days at 20-30°C.
Sitka spruce, Douglas fir, Western hemlock and Japanese larch	21 days at 20-30°C after 21 days moist prechilling at 2°C.
Lodgepole pine	28 days at 20-30°C after 21 days moist prechilling at 2°C.

All fresh ungerminated seed remaining at the end of the prescribed test period were tested with tetrazolium, and the "viable seeds" added to the actual germination value as a "plus figure". In this report, the abbreviation "CT+" is used to refer to the combined values obtained by this Copenhagen Tank method, thus, 67 + 3%=CT+=70%.

The data assembled was subjected to statistical analysis to establish the linear dependence of tetrazolium "A" and "A+B" values on "CT+" values and species. In addition, regression functions were calculated to provide a means of obtaining the best estimate of "CT+" values from tetrazolium test values. The results of all tetrazolium and Copenhagen tank check tests were averaged for the numbers of samples listed in Table 38, and these averages, together with calculated correlation coefficients, are presented in Table 39 below:

Table 39

Overall Average Values for Tetrazolium and Copenhagen Tank Tests and the Correlation Coefficients between the Values

Species	Average Tetrazolium percentage based on staining groups:		Average Copenhagen Tank Germination percentage:		Correlation* Coefficients of CT+ percentage with:	
	"A"	"A+B"	CT	CT+	"A"	"A+B"
Scots pine	65	72	69	70	.935	.950
Corsican pine	62	73	64	64	.808	.810
Lodgepole pine	64	76	80	83	.667	.758
European larch	26	30	29	29	.910	.912
Japanese larch	32	36	37	40	.889	.914
Norway spruce	48	56	53	53	.879	.957
Sitka spruce	53	62	57	59	.968	.965
Douglas fir	57	65	56	65	.931	.949
Western hemlock	40	49	53	58	.908	.913
Grand fir	24	36	15	18	.740	.765
Noble fir	17	25	18	19	.776	.721

Note: **Correlation coefficient* is a measure of linear correlation, which can take values between +1 and —1. A value near to +1 indicates almost perfect positive association, high values of one variable occurring with high values of the other.

It is clear from this table that the correlation between CT+ results on the one hand, and tetrazolium values on the other, varies between species, and tetrazolium "A" and "A+B" values. Inspection of the correlation coefficients shows that in nearly all cases, "CT+" results are more closely correlated with "A+B" results than with "A" results of the tetrazolium test. Similarly, between species, these results were less closely correlated for lodgepole pine, noble fir and grand fir than for other species.

The main interest and purpose in comparing the results of the two methods of germination test is to examine the precision with which tetrazolium results can be used to provide an estimate of seed quality, expressed in terms of "CT+" values. Calculation of the *regression equations** of "CT+" values on tetrazolium "A" and "A+B" results, provides a set of formulae for the most efficient estimation possible of "CT+" values on the basis of the available data. The calculated equations and the standard deviations† of the actual points about the functions are presented in Table 40. The graphs of the regression equations are drawn in Figures 12 and 13.

Table 40

Regressions of Seed Quality ("CT+" Values), on Tetrazolium Test Results, and the Standard Deviations about these functions

Species	On Tetrazolium "A" values		On Tetrazolium "A+B" values	
	Regression Equation*	Standard† Deviation	Regression Equation*	Standard† Deviation
Scots pine	4.6+("A")	8.6	2+0+("A+B")	7.5
Corsican pine	("A")	17.5	("A+B")	17.4
Lodgepole pine	18.6+("A")	13.1	7.0+("A+B")	11.2
European larch	3.0+("A")	6.0	("A+B")	5.9
Japanese larch	8.5+("A")	8.0	3.8+("A+B")	7.1
Norway spruce	—1.0+1.14 ("A")	13.2	("A+B")	8.5
Sitka spruce	—1.0+1.14 ("A")	7.4	—2.3+("A+B")	7.7
Douglas fir	7.5+("A")	10.2	5.4+0.89 ("A+B")	8.9
Western hemlock	17.6+("A")	9.2	8.9+("A+B")	8.9
Grand fir	—5.6+("A")	11.9	—4.0+0.62 ("A+B")	11.4
Noble fir	2.3+("A")	7.7	3.6+0.62 ("A+B")	8.5
Grand fir ("A" embryo in "A" endosperm)....	("A" in "A")	14.8		
Noble fir ("A" embryo in "A" endosperm)....	6.6+("A" in "A")	4.9		

Notes: **Regression Equation*=an equation expressing the relationship between a specified tetrazolium test result and the mean of all corresponding values of "CT+" tests.

†*Standard Deviation*=a measure of the dispersion of the population from the regression function.

The standard deviations about the regression functions are an expression of the reliability of an estimate of seed quality obtained by applying the regression equation to a tetrazolium test result. They may be regarded as minimum values of the standard deviation of an estimate of seed quality. It can be seen from the table that estimation is significantly less successful for some species than others and, generally, standard deviations are higher for tetrazolium "A" results than for "A+B" values. The highest standard deviations occurred with Corsican

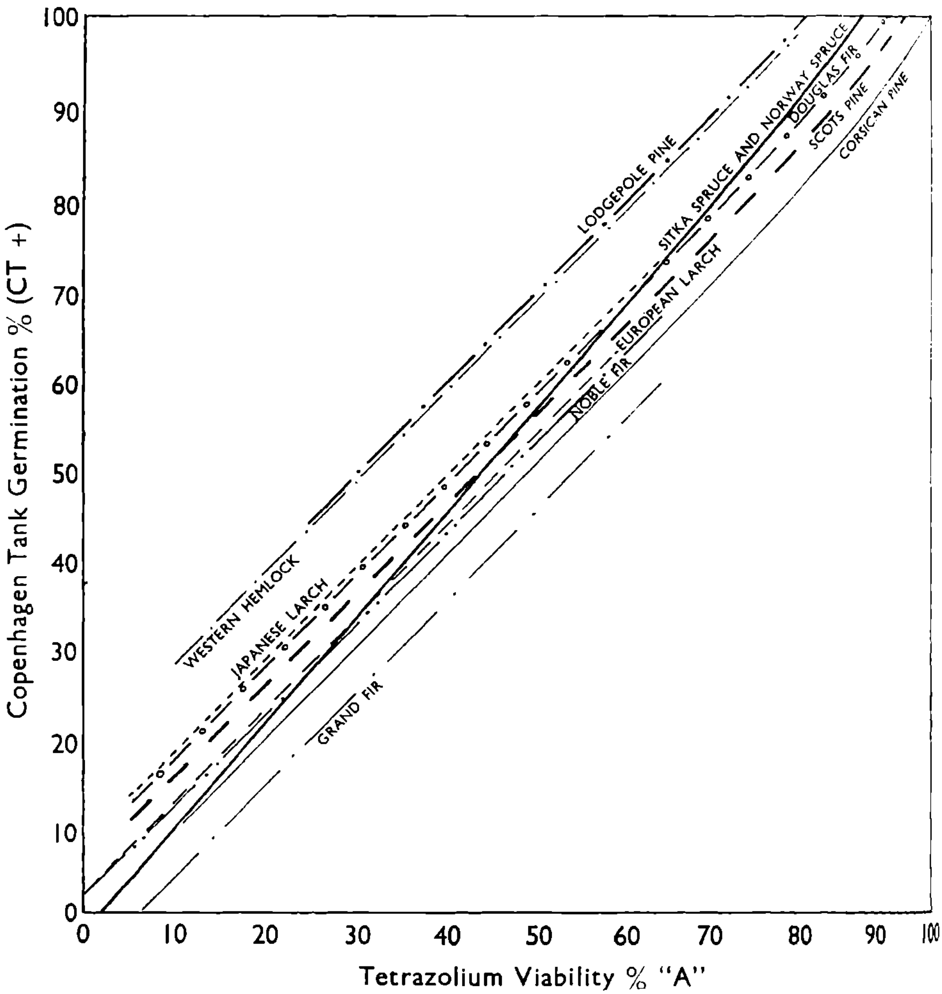


FIG. 12. Regressions of Copenhagen Tank (CT+) Results on Tetrazolium "A" Results, for eleven conifers.

pine, lodgepole pine and grand fir, the values for all other species being at a broadly similar level.

Inspection of the regression equations shows that tetrazolium "A+B" values generally provide a closer approximation to "CT+" results than do tetrazolium "A" values. It can also be seen that "A+B" values provide a close estimate of seed quality in terms of "CT+" results for European larch and Norway spruce, and only a small correction is necessary to "A+B" values for Scots pine, Japanese larch, Douglas fir and Sitka spruce. Corsican pine showed very variable results and the "A+B" value is not a very safe prediction of "CT_+", owing to the big standard deviation around the regression function.

Without correction, "A+B" values are likely to give a slight under-estimate of seed quality for Scots pine, Japanese larch and Douglas fir, and a slight over-estimate for Sitka spruce. Less satisfactory regressions were obtained with lodgepole pine and western hemlock, for which "A+B" results considerably

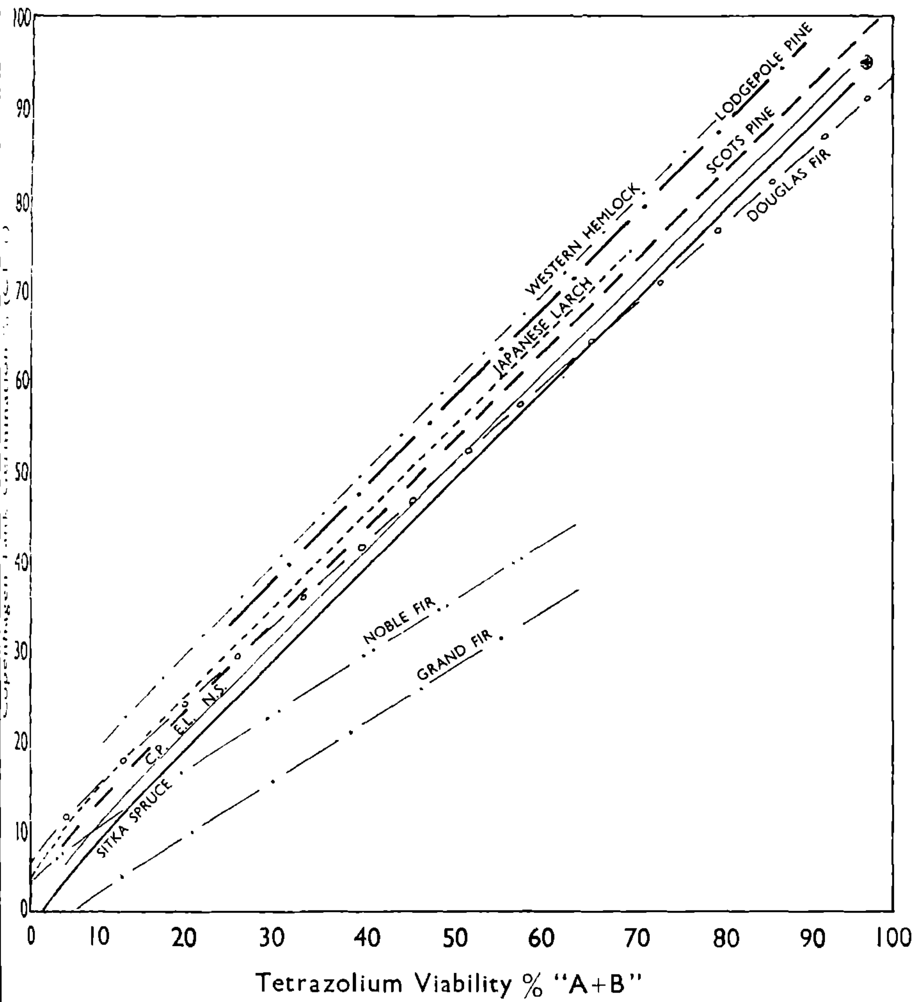


FIG. 13. Regressions of Copenhagen Tank (CT+) Results on Tetrazolium "A+B" Results, for eleven conifers.

Note. C.P.=Corsican pine, E.L.=European larch, N.S.=Norway spruce.

under-estimated seed quality. This is difficult to explain. The seed of these species are among the smallest and most difficult to handle, and maybe the present procedure or embryo classification scheme is unsuited to these species. However, an estimate of seed quality can be obtained by applying the regression equation.

For *Abies* species, tetrazolium "A+B" results were much too high, and clearly, values based on "A" results provide a much closer estimate. In an effort to improve the technique for *Abies* species, assessment of endosperm staining, in addition to embryo staining, was introduced for all routine tests in 1957, but only 28 such tests have been completed so far. In these tests only seeds containing fully stained embryos within a fully stained endosperm are classified as viable in the tetrazolium test. The regression equations and standard deviations for these extra tests are given at the foot of Table 40; and suggest that values of fully stained ("A") embryos in fully stained ("A") endosperm, are no better than embryo "A" values alone as estimates of "CT+" results.

In making general conclusions on the practical value of the tetrazolium test, it must be remembered that a quite considerable degree of manipulative skill is required in completing the test satisfactorily. It may be a practical disadvantage. but it is true to say that the test should only be done where a trained and skilled analyst is available. The tests contributing to all the data here presented were completed by one experienced analyst. The results recorded serve to illustrate the general relationship found between tetrazolium and Copenhagen tank tests in practice, and the regression equations computed will assist in obtaining a more reliable estimate of seed quality than has been possible hitherto, using the procedure described.

On the question of interpretation of embryo-staining categories in the tetrazolium test, all seed were judged on the basis of the distribution of colour, and in this respect it was close to Lakon's topographical method. It may be that attention should also be paid to the intensity of staining as proposed by Bennet and Loomis (1949), but more observations are required to assess the significance of colour intensity.

Summary

(1) The report describes the development and technique of the tetrazolium bromide ("Grodex"), as used at the Alice Holt Seed Testing Laboratory for routine viability tests on seeds of common conifers in the period 1949-57. The species examined were Scots pine, Corsican pine, lodgepole pine, European and Japanese larch, Norway spruce, Sitka spruce, Douglas fir, grand fir and noble fir.

(2) The test technique as described is based on the distribution of stained regions in seed embryos after immersion in tetrazolium solution, the following staining classes being recorded as viable seeds:

"A"—Fully stained embryos.

"B"—Embryos with unstained parts less than 1/6th of the total surface.

(3) The results of a total of 766 tests on 11 species are analysed, together with the results of standard Copenhagen tank germinator tests which were completed on parallel samples for all lots.

(4) Regression equations for the most efficient estimation of Copenhagen tank results, from the results of the tetrazolium test, are calculated and presented. For the majority of species, viable seed percentage, as indicated by the tetrazolium "A+B" values, gave the best estimate of seed quality in terms of Copenhagen tank values. Among the species examined, the tetrazolium test gave the least satisfactory results for western hemlock, lodgepole pine and Corsican pine.

(5) Examination of endosperm as well as embryo staining in the tetrazolium test for *Abies* species failed to indicate any clear means of improving on the estimates of quality based only on embryo staining.

REFERENCES

ANON (1956). International Rules for Seed Testing. *Proc. Int. Seed. Test. Asscn.* Vol. 21(1) pp. 80.

N. BENNETT and W. E. LOOMIS (1949). Tetrazolium Chloride as a Test Reagent for Freezing Injury of Seed Corn. *Plant Physiology* 24(1): 162-174.

F. E. EIDMANN (1937). Ein neuer Weg der Saatgutprüfung. *Der Forschungsdienst* 3 (9): 448-455.

S. F. GOODSELL (1948). Triphenyltetrazolium Chloride for Viability Determination of Frozen Seed Corn. *Jour. Americ. Soc. of Agron.* 40 (5): 432-442.

R. HILF and E. ROHMEDER (1955). Untersuchungen über das Verhalten von Tetrazoliumchlorid bei der Keimfähigkeitsprüfung forstlicher Sämereien. *Forstw. Cbl.* 74: 257-320.

W. KRZESZKIEWICZ (1939). Okreslenie potencjalnej zdolnosci kielkowania nasion sosny za pomoca metody barwienia. (Determining the viability of Pine seeds by means of the indigo-carmine test). *Inst. Rech. For. Poland Trav. et Comptes Rendus Ser.* A No. 44 pp. 45 (*For. Abstr.* 1(2)).

KUHN and JERCHEL (1941). Reduction von Tetrazoliumzalzen durch Bakterien, gärende Hefe und keimende Samen. *Ber. Deutsch. Chem. Ges.* 74 B: 941, 949.

G. LAKON (1940). Die topographishe Selenmethode, ein neues Verfahren zur Feststellung der Keimfähigkeit der Getreidefrüchte ohne Keimversuch. *Proc. Int. Seed Test. Asscn.* 12 (1):1-18.

G. LAKON (1942). Topographischer Nachweis der Keimfähigkeit der Getreidefrüchte durch Tetrazoliumsalze. *Ber. Deutsch. Bot. Ges.* 60:299-305.

G. LAKON (1947). The Topographical Tetrazolium Method for determining the germinating capacity of seeds. *Plant Physiology* 22 (3):389-394.

G. LAKON (1949). Die Anwendung meines topographischen Tetrazoliumverfahrens zur Feststellung der Keimfähigkeit der Kern und Steinobstsamen. *Saatgutwirtschaft* 1 (3):51-53.

G. LAKON (1950). Die Feststellung der Keimfähigkeit der Konifernsamen nach dem topographischen Tetrazoliumverfahren. *Saatgutwirtschaft* 4:83-87.

A. M. MACLEOD (1950). Enzyme Activity in Relation to Barley Viability. *Tran. and Proc. of the Bot. Soc. of Edinburgh.* Vol. 36 (1):18-33.

E. ROHMEDER (1940). Erfahrungen mit dem "Selenverfahren" bei der Untersuchung des Forstliches Saatgutes. *Allg. Forst u. Jagdztg.* 116:169-188. For. Astr. 3 (2).

F. G. SMITH (1952). The Mechanism of the Tetrazolium Reaction in Corn Embryos *Plant Physiology* 27:445-456.

USE OF A FRACTIONALLY-REPLICATED DESIGN IN A PILOT SURVEY OF MOISTURE CONTENT AND SPECIFIC GRAVITY OF SPRUCE AND PINE BARK

By J. N. R. JEFFERS and R. S. HOWELL

Introduction

892.4:015.5

There has been considerable interest in the use of spruce and pine bark as sources of tannin and other extractives, and estimates have been made of the volume of bark produced as a by-product from the thinnings of plantations. In

Commission plantations over England, Wales, and Scotland, the distribution of the samples in the Conservancies was weighted so that most samples were taken in those Conservancies with the biggest acreages of the species. Table 42 gives the number of acres of each species, over and under 41 years of age, in each Conservancy, and Table 43 gives the allocation of the samples to Conservancies. Each Conservator was asked to provide bark samples from stands with the required characteristic, and which were being thinned at the correct time.

Results of Survey

Three variables were measured on each sample of bark, the normal specific gravity, the basic specific gravity, and the moisture content. The normal specific gravity is defined as the *fresh* weight of the bark, divided by the weight of an equivalent volume of water. Basic specific gravity is defined as the *oven-dry* weight of the bark divided by the weight of an equivalent volume of water. Both densities are believed to be slightly under-estimated in this survey because of swelling of the bark during the volume determinations. Moisture content is defined as the difference between the fresh weight and the dry weight of the bark, divided by the *dry* weight. Differences in moisture content may, therefore, be due to differences of the weight of water in a given volume or to differences in the dry weight.

Scots and Corsican Pines

The mean values of the normal specific gravity, basic specific gravity, and moisture content of the barks of Scots and Corsican pines for six factorial comparisons, are given in Table 44.

The overall average normal specific gravity of pine bark was found to be 0.712, with a standard error of ± 0.018, and a standard deviation of 0.101. The density of the Corsican pine bark was appreciably, but not significantly, greater than that of the Scots pine bark. Bark collected in summer, however, had a very significantly greater normal specific gravity than bark collected in winter, and bark from the tops of the trees was very significantly denser than bark from the butts. The position of the thinnings in the canopy, age of the trees, and quality class of the stand, had no significant effect on the normal specific gravity.

The overall average basic specific gravity was 0.354, with a standard error of ± 0.007, and a standard deviation of 0.042. The basic specific gravity of Corsican pine was significantly greater than that of Scots pine, and, again, bark collected in summer was significantly denser than bark collected in winter.

The average moisture content of pine bark was 106 per cent, with a standard error of ± 5.9 per cent, and a standard deviation of 33.3 per cent. There was no significant difference between the moisture contents of Scots and Corsican pine barks, and season of collecting the bark, position of the trees in the canopy, age of the trees, and the quality class of the stand had no significant effect on the moisture content. Bark from the tops of the trees, however, had a very significantly higher moisture content than bark from the butts, and, as there was no appreciable difference in basic specific gravity of bark from the two positions, the differences in moisture content must be attributed to differences in the amount of water per unit volume of bark.

Norway and Sitka Spruce

The mean values of the normal specific gravity, basic specific gravity, and moisture content of the Norway and Sitka spruces, for six factorial comparisons, are given in Table 45.

Table 42

Distribution of Scots and Corsican pine, and Norway and Sitka spruce in Forestry Commission Plantations, by Conservancies

Conservancy		Number of acres of species in age classes:—							
		Scots pine		Corsican pine		Norway spruce		Sitka spruce	
		$\leqslant 41$	41+	$\leqslant 41$	41+	$\leqslant 41$	41+	$\leqslant 41$	41+
England	South-East	4,502	109	673	30	826	6	295	2
,,	South-West	2,632	40	1,333	—	3,203	10	5,529	—
,,	Dean Forest	405	20	332	—	1,403	14	440	—
,,	New Forest	6,314	4,173	3,299	9	557	5	487	—
,,	East	30,651	314	10,879	58	1,195	25	1,024	—
,,	North-East	7,535	70	1,805	—	14,397	89	21,872	—
,,	North-West	5,201	169	7,534	126	4,089	12	8,647	—
Scotland	South	3,244	60	257	—	6,809	115	13,127	1
,,	West	3,234	151	62	—	15,045	81	27,394	59
,,	East	20,755	978	2,759	86	8,655	13	13,459	8
,,	North	13,672	1,521	41	5	8,310	48	16,119	—
Wales	North	1,672	3	112	—	11,396	42	18,225	16
,,	South	3,008	6	2,440	—	6,449	29	13,725	—

Table 43

Allocation of sample numbers to Conservancies

Sample number (as in Table 41):

Conservancy		Scots pine		Corsican pine		Norway spruce		Sitka spruce	
		⩽41	41+	⩽41	41+	⩽41	41+	⩽41	41+
England	South-East	—	—	—	5	—	—	—	—
,,	South-West	—	—	—	—	—	—	—	—
,,	Dean Forest	—	—	—	—	—	—	—	—
,,	New Forest	16	20, 27, 1, 22	32	—	—	—	—	—
,,	East	7, 28, 23	4	30, 13, 12	10, 19	—	—	—	—
,,	North-East	14	—	—	—	16	2, 21	11	—
,,	North-West	—	—	11, 6	18, 26, 17	—	—	—	—
Scotland	South	—	—	—	—	—	20	6	—
,,	West	—	—	—	—	15, 23	4	29, 32	19, 5, 8, 17, 10, 26
,,	East	25, 15	21	31	9, 8	14	—	31	9
,,	North	24	—	—	—	25	—	12	—
Wales	North	—	—	—	—	7	1, 27	30	18
,,	South	—	—	—	—	24, 28	22	13	—

Table 44

Mean values of normal specific gravity, basic specific gravity and moisture content for pine barks

Factor		Normal specific gravity	Basic specific gravity	Moisture Content
Species	Scots pine	0.674	0.324	113
	Corsican pine	0.750	0.384**	98
Season	Summer	0.779	0.393	101
	Winter	0.644**	0.315**	110
Position	Top	0.822	0.346	145
	Butt	0.602**	0.362	66**
Dominance	Co-dominant	0.714	0.360	102
	Suppressed	0.709	0.348	110
Age	41 years and less	0.718	0.350	112
	Over 41 years	0.706	0.358	100
Quality Class	Q.C. I	0.714	0.342	114
	Q.C. III....	0.710	0.365	97
Standard errors	....	±0.026	±0.010	±8.3

Note: **Significant at 0.01.

Table 45

Mean values of normal specific gravity, basic specific gravity and moisture content for spruce barks

Factor		Normal Specific gravity	Basic Specific gravity	Moisture content
Species	Norway spruce	0.843	0.380	127
	Sitka spruce	0.863	0.358	146
Season	Summer	0.923	0.394	140
	Winter	0.783**	0.344**	134
Position	Top	0.850	0.331	159
	Butt	0.856	0.407**	114**
Dominance	Co-dominant	0.891	0.386	137
	Suppressed	0.815*	0.352	137
Age	41 years or less	0.880	0.358	150
	over 41 years	0.826	0.380	124*
Quality class	Q.C. I	0.862	0.374	136
	Q.C. III	0.844	0.364	138
Standard errors	....	±0.021	±0.011	±6.2

Notes: *Significant at 0.05. **Significant at 0.01.

The overall average normal specific gravity of spruce bark was 0.853, with a standard error of ±0.015, and a standard deviation of 0.083. Bark collected in summer had a very significantly greater normal specific gravity than bark collected in winter, and bark collected from dominant trees was denser than bark collected from suppressed trees.

The overall average basic specific gravity of spruce bark was 0.369, with a standard error of ±0.008, and a standard deviation of 0.045. Bark collected in summer had a very significantly greater basic specific gravity than bark collected in winter, and bark from the butts of the trees was very significantly denser than bark from the tops.

For neither normal nor basic specific gravity was there a significant overall difference between the densities of bark from Norway and Sitka spruces, but there were interactions between the effects of species and age of the trees, and between the effects of species and the age of the trees as shown in Table 46.

Table 46

Interactions between the effects of age and season of pruning on normal and basic specific gravity of spruce bark

	Normal specific gravity		Basic specific gravity	
41 years old and under: summer collection	0.985	±.029*	0.404	±.016*
„ „ „ „ „ winter „	0.775		0.312	
Over 41 years old: summer collection	0.861		0.384	
„ „ „ „ winter „	0.791		0.377	

* Significant at 0.05.

For both normal and basic specific gravity, the fall from summer to winter was greater in the younger age class than in the older class, in which it did not reach statistical significance. Only in the summer was there any appreciable difference in the normal specific gravity of the bark of trees of the two age classes, and only in the winter was there a significant difference in the basic specific gravity of bark from trees of the two age classes, as shown in Table 47.

Table 47

Interactions between the effects of age and species on normal and basic specific gravity of spruce bark

	Normal specific gravity		Basic specific gravity	
41 years old and under: Norway spruce	0.837	±.029*	0.343	±.016**
„ „ „ „ „ Sitka „	0.923		0.372	
Over 41 years old: Norway spruce	0.850		0.418	
„ „ „ „ Sitka „	0.802		0.343	

* Significant at 0.05. ** Significant at 0.01.

The normal specific gravity of the bark of the younger Sitka spruce was appreciably greater than that of Norway spruce of both age classes, and that of the older Sitka spruce was appreciably smaller than that of the Norway. While the basic specific gravity of Sitka spruce bark tended to fall with increasing age, that of Norway spruce bark showed a very significant rise with increasing age.

The average moisture content of the spruce bark was 137 per cent, with a standard error of ± 4.4 per cent, and a standard deviation of 25.0 per cent. As for pine bark, the moisture content was greater in bark from the tops of the trees than in samples from the butts, but, in contrast to pine bark, the rise in moisture content was due to the fall in basic specific gravity, the normal specific gravity remaining approximately constant. The significant fall in moisture content with increasing age in the spruces was accompanied by a non-significant fall in normal specific gravity, and a rise in basic specific gravity.

The normal specific gravity of the bark of both pines was significantly lower than that of both spruces. The basic specific gravity of Corsican pine bark was, on the average, not greatly different from that of the spruces, but that of Scots pine was significantly lower than that of the spruces. The bark of both pines had rather lower moisture contents than those of the spruces, Sitka spruce having the bark with the highest moisture content.

Summary and Conclusions

The survey achieved its object in providing an estimate of the average moisture content and specific gravity of pine and spruce bark, and an estimate of the variability of these variables. Future surveys can now be planned to achieve standard errors of any required size, using the coefficients of variation estimated by the present survey. It is of interest to note that, while the coefficient of variation of the moisture content of the spruce bark was only 18 per cent, that of pine bark was 32 per cent. Thus, to estimate average moisture contents of pine and spruce bark with standard errors of about the same size, a considerably larger number of samples of pine bark than of spruce bark would be required.

The survey has also given valuable information on the stratifications which are likely to be important for future surveys. Thus, for moisture content, it is necessary to stratify the population to be sampled by the position in the tree from which the samples are to be obtained, and by the age of the trees. Other factors, for example, those of species, season of collection, position of the crowns of the trees in the canopy, and quality class of the stand, can all be safely ignored. The use of the device of the fractional replication of a 2^6 factorial design, therefore, very greatly increased the information which was obtained from a pilot survey of very modest size.

The work was done for the Utilisation Development Section at the instance of Mr. J. R. Aaron, who arranged the supply of the bark samples for testing.

SCOTTISH EXPERIMENTS COMPARING CHLOROPICRIN WITH FORMALIN AS A PARTIAL SOIL STERILIZER FOR CONIFER SEEDBEDS

By R. FAULKNER

232.322.2

Chloropicrin has been successfully used for the partial sterilization of horticultural and forest nursery soils in many parts of the world during the last decade. Smith (1939) gave one of the fullest descriptions of the techniques and results of application of chloropicrin to horticultural soils, and Lindgren and

Birch (1949) and Maki and Birch (1951) reported favourably on chloropicrin as a soil sterilization agent in forest nurseries in some southern states in the United States of America.

It was on account of difficulties, chiefly in connection with the import of the chemical from abroad, that full scale experiments had to be delayed until 1952, although in 1951 a small scale demonstration of chloropicrin and formalin treatments was sown with Sitka spruce in the Royal Botanic Garden, Edinburgh. The seedlings in this early trial were badly damaged by birds, but the few surviving plants grew strongly and, those raised on chloropicrin-treated soil were superior in appearance to seedlings raised on both the formalin-treated and untreated soil alongside.

In order to test the sterilizers on different soil types and under different climatic conditions, the experiments to be described were carried out at three nurseries in 1953, at six nurseries in 1954, and at five nurseries in 1955. The soil types of the nurseries concerned can be classified on a texture basis as follows:– Inchnacardoch, peaty-sand; Newton, silty sand; Fleet, medium-loam; Bush, medium-silty-loam; Tulliallan, silty-clay-loam; and Wykeham, heavy-silty-loam.

Notes on the Sterilizers

(a) *Formalin.* Formalin is sold as a thirty-eight per cent solution of formaldehyde in water. It is normally applied to seedbeds at the rate of between five and ten gallons, diluted with one hundred and fifty gallons of water, per hundred square yards. This rate of application is based on the experimental results obtained by Edwards (1952). The chemical is a relatively cheap commodity and cost four and ninepence per gallon in 1957. However, it is both costly to mix with water and costly to apply, on account of the handling difficulties of large volumes of solution, and on account of the slow rate of absorption of the solution into the soil.

(b) *Chloropicrin.* Roark (1934) gives a very full description of the chemical which is known technically as "nitrochloroform" or "trichlornitromethane" and has the formula CCl_3NO_2. At normal temperatures it is a colourless liquid with a boiling point of 112.4°C, a specific gravity of 1.69 at 0°C, and a very low solubility in water. It is superior to some other fumigants in that it is non-inflammable and that it does not react with fabrics and colours under fumigating conditions, but it can start corrosion on unpainted or unvarnished ferrous metals. It has a very pungent odour and lachrymatory effect. Its odour is persistent and is removed with some difficulty. Chloropicrin is relatively toxic to living plants and seeds, and in some trials chloropicrin which has been injected into experimental seedbeds has caused severe foliage damage to conifer transplants growing within fifteen yards of the treated soil.

Chloropicrin is expensive and costs £6 5s. 0d. per gallon in 1957. Because of the very low rate of application required for satisfactory soil sterilization, the chemical can easily be applied by machine at a very low cost.

Experimental Procedure

Seedbeds three feet six inches wide were prepared and roughly levelled, soil sterilization treatments were then applied to randomized plots, using a three feet six inches square plot as a sterilization unit.

Diluted formalin solutions were applied to seedbeds with a garden watering can fitted with a rose. The dilution was in the ratio of five or ten gallons of formalin, depending upon the year of the experiment, to one hundred and fifty gallons of water per one hundred square yards.

Injection of the chloropicrin was made either by a hand-operated "Fumigun", by a Shell DD injector gun, or by hand—pouring measured quantities of the liquid with the aid of a polythene funnel into prepared one inch diameter holes in the seedbed. There were eight equidistant injection points over the three and a half feet square sterilizing area. In the series of experiments, chloropicrin was applied at between 0.21 to 1.45 gallons per one hundred square yards (ten to seventy gallons per acre). The depth of injection varied from three to five inches in different experiments. After applying the chloropicrin the injection holes were filled in with soil, which was then lightly firmed by hand.

Two weeks before sowing the seed all plots were cultivated to a depth of three to four inches to allow any residual vapours to escape. A few days before sowing, phosphate and potash fertilizers were applied at rates sufficient to ensure that the levels of phosphorus and potassium in the soil were adequate for the crop of seedlings. Nitrogen was applied in two top dressings in July as "Nitrochalk" to provide a total of twenty-five ounces nitrogen per one hundred square yards. The species used in all experiments was Sitka spruce. Seed was sown in the centre square yard of each plot and covered with three-sixteenths of an inch of grit or coarse sand.

The 1953 Experiments

Chloropicrin was injected into the soil three to four weeks before sowing the seed, at either 0.42, 0.63 or 0.84 gallons per hundred square yards, these rates being equivalent to twenty, thirty or forty gallons per acre, and at depths of either three or five inches below the soil surface. Formalin was applied as a dilute solution containing five gallons of formalin per hundred square yards. The two depths of chloropicrin injection treatments were factorially combined with the three rates of application treatments, and these were compared with the formalin treatments, and with an unsterilized control treatment in four randomized blocks.

At Newton and Benmore, the mean effect of the three chloropicrin treatments on heights was a slight, but not a significant, increase in comparison with formalin. At Fleet, chloropicrin produced a highly significant height increase in comparison with formalin. Both formalin and chloropicrin caused very pronounced height increases at all three nurseries when compared with the controls.

Chloropicrin reduced the yield of seedlings at both Benmore and Fleet. At Benmore the reduction in yield was highly significant when compared with either the formalin treatment or the control.

Both sterilizers significantly reduced the weeding times at Benmore but not at Fleet. Weeding times were not assessed at Newton.

There was a consistent trend towards taller seedlings with increasing concentrations of chloropicrin, but significant differences were only established at Newton, where the heaviest rate of application produced a highly significant increase in heights when compared with the lowest rate, and a significant height increase over the middle rate of application.

The yield of seedlings was not greatly affected by the rate of application of chloropicrin.

Although weeding times were greatly reduced by the higher concentration of chloropicrin, there were no significant differences between the three rates of application.

The depth of injection of chloropicrin did not significantly affect the heights or yields of seedlings or the weeding times.

The 1954 Extension of the 1953 Experiment

Plants from the 1953 experiments were carefully lifted in the early spring of 1954, and the plots were re-sown with Sitka spruce seed, after phosphate and potash fertilizers had been applied to all plots.

Assessments carried out on the resulting crop of seedlings in the following late autumn showed that height difference between the control, formalin and all chloropicrin-treated plots at Fleet and Newton were negligible, but at Benmore, although the difference in height between the chloropicrin and the formalin or control plots was small (0.20-0.25 inches), it was highly significant. There were no residual effects of the sterilizers on the yields of seedlings. See Table 48.

Table 48

Heights, numbers per square yard and weeding times, in minutes per square yard of 1+0 Sitka Spruce raised on Chloropicrin- and Formalin-treated soils in 1953

Treatment	Mean Ht. (inches)			Total Nos. per sq. yard			Weeding Times mins./sq. yd.	
	Newton	Benmore	Fleet	Newton	Benmore	Fleet	Benmore	Fleet
Chloropicrin								
0.42 galls. per 100 sq. yds.	1.79	1.50	3.18	1175	1179	1089	3.1	10.8
0.63 „ „ „ „ „	1.99	1.54	3.33	1184	1170	1071	2.6	9.6
0.84 „ „ „ „ „	2.24	1.69	3.60	1153	1125	1062	2.8	6.0
Standard Error ±	0.08	0.08	0.14	63	36	45	0.2	0.78
Differences for significance 5%	0.23	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.
Differences for significance 1%	0.31							
Chloropicrin (Mean of 3 levels detailed above)	2.01	1.58	3.37	1170	1161	1071	2.8	8.8
Formalin	1.95	1.32	2.13	1215	1269	1161	2.6	7.2
Control	1.29	0.82	1.80	1107	1377	1233	4.2	8.8
Standard Error ±	0.09	0.18	0.16	72	36	45	0.2	0.87
Differences for significance 5%	0.26	0.25	0.46	Not sigt.	108	Not sigt.	0.7	Not sigt.
Differences for significance 1%	0.35	0.33	0.62		153		1.0	
*Depth of Application**								
3 inches	1.96	1.52	3.30	1230	1179	1071	2.6	8.8
5 inches	2.05	1.62	3.36	1111	1152	1080	2.8	8.8

Note: *Differences not significant at any nursery for mean heights, total numbers or weeding times.

The 1954 Series of Experiments

In 1954, a wider range of concentrations of chloropicrin was tested namely, 0.21, 0.52, 0.84, 1.14 and 1.45 gallons per hundred square yards, these rates are equivalent to ten, twenty-five, forty, fifty-five and seventy gallons per acre.

Chloropicrin was injected to a depth of four inches in all treatments. Applications were made ten, twenty or thirty days before sowing, in order to determine the safe time lapse between injection and sowing date. Formalin was also applied either ten, twenty or thirty days before sowing, at a rate of ten gallons of formalin in one hundred and fifty gallons of water per hundred square yards.

The four highest concentrations of chloropicrin caused a very pronounced reduction in the rate of germination, at all six nurseries during the early stages of germination. In addition applications which were made ten or twenty days before sowing also seriously slowed down the rate of germination. To illustrate these points data from the Fleet experiment are given in Table 49.

Table 49

Numbers of Sitka Spruce Seedlings per square foot during the period of Germination

(Fleet 2. P54. D.L.)

Treatment	1st Count 26/5/54	2nd Count 8/6/54	3rd Count 21/6/54	4th Count 2/7/54
Sterilization (mean of 3 dates)				
Chloropicrin 0.21 galls./100 sq. yds.	23	78	107	108
„ 0.52 „ „ „	12	52	83	87
„ 0.84 „ „ „	10	40	66	74
„ 1.14 „ „ „	2	19	40	50
„ 1.45 „ „ „	1	11	32	40
Formalin 10 (diluted) „ „ „	27	85	116	124
S.E. ±	2	5	5	5
Critical difference 5%	6	13	13	15
Critical difference 1%	9	18	18	20
Date of Application (mean of all sterilization treatments)				
10 days before sowing	9	39	66	71
20 „ „ „	10	38	61	70
30 „ „ „	19	65	94	99
S.E. ±	1.5	3	3	4
Critical difference 5%	4.5	9	9	11
Critical difference 1%	6.0	12	12	14

At the end of the growing season, the higher concentrations of chloropicrin produced taller seedlings than the lowest concentrations at three of the nurseries; but at Benmore, Fleet and Wykeham the highest rate of application was harmful and led to shorter seedlings in comparison with the middle and lower rates of application. See Table 50. This may possibly have been due to the retardation of germination and consequent reduction in the length of the growing season.

From Table 50 it can be seen that at all nurseries excepting Benmore, chloropicrin was generally more effective than formalin and produced taller seedlings. Overall it appeared that chloropicrin at 0.52 to 0.84 gallons per hundred square yards produced similar height growth to formalin applied at ten gallons per hundred square yards.

Table 50

Mean Heights, Total numbers per square yard and Weeding Times in minutes per square yard of Sitka Spruce 1+0 *Seedlings raised in* 1954 *on soils treated with Chloropicrin and Formalin* 10, 20 *or* 30 *days before sowing*

Sterilizers Gallons per 100 sq. yds.	Mean height in inches						Total Numbers per square yard						Weeding times in mins./sq. yard					
	Inchna-cardoch	New-ton	Ben-more	Tulli-allan	Fleet	Wyke-ham	Inch.	New.	Ben.	Tull.	Flt.	Wyke.	Inch.	New.	Ben.	Tull.	Flt.	Wyke.
Chloropicrin 0.21	0.71	1.73	1.78	1.27	1.25	1.27	1,253	1,271	958	1,073	850	1,627	45	3	14	18	5	12
„ 0.52	0.81	1.82	2.11	1.42	1.39	1.27	1,328	1,224	905	1,038	745	1,616	38	4	13	20	6	12
„ 0.83	0.98	2.08	2.13	1.79	1.58	1.63	1,310	1,376	702	1,094	612	1,688	28	4	10	18	5	10
„ 1.14	0.97	2.17	1.94	1.87	1.39	1.50	1,300	1,260	673	1,071	450	1,649	28	4	11	16	5	10
„ 1.45	1.09	2.31	1.51	1.90	1.26	1.50	1,246	1,260	497	1,034	418	1,494	25	4	8	14	6	14
Formalin 10	0.74	1.62	2.15	1.49	1.40	1.11	1,382	791	1,073	1,178	914	1,415	28	3	15	16	5	17
S.E. ±	0.032	0.07	0.06	0.06	0.06	0.09	51	53	40	45	44	60	2	0.3	1	1	0.5	3
Critical Difference 5%	0.09	0.20	0.16	0.18	0.16	0.26	Not sigt.	153	114	Not sigt.	127	Not sigt.	5.4	1	3	4	Not sigt.	Not sigt.
Critical Difference 1%	0.12	0.28	0.21	0.24	Not sigt.	0.35		206	154		171		7.3	Not sigt.	4	Not sigt.		
No. days before sowing																		
10	0.90	1.89	1.76	1.50	1.33	1.34	1,296	1,168	713	1,052	612	1,516	32	4	12	18	6	11
20	0.92	1.90	1.92	1.61	1.32	1.37	1,354	1,161	788	1,109	601	1,609	27	3	11	18	5	12
30	0.82	2.07	2.12	1.76	1.48	1.43	1,256	1,262	896	1,082	778	1,620	37	4	12	16	4	9
S.E. ±	0.024	0.055	0.03	0.04	0.03	0.06	36	38	28	32	31	42	1	0.2	1	2	0.5	1
Critical Difference 5%	0.06	0.16	0.09	0.13	0.09	Not sigt.	Not sigt.	Not sigt.	80	Not sigt.	90	Not sigt.	3.8	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.
Critical Difference 1%	Not sigt.	Not sigt.	0.12	0.17	0.12				109		121		5.2					
Demonstration unsterilized plots. Mean of three	0.43	1.25	1.25	0.81	1.23	1.03	1,202	1,250	1,281	1,010	846	1,593	44	3	13	16	9	7

Except at Inchnacardoch, the tallest seedlings were produced when sterilizers had been applied thirty days before sowing, and the smallest seedlings were produced on areas where the time lapse had been only ten days.

The higher rates of chloropicrin drastically reduced the final seedling yields at Benmore and Fleet, and it is interesting to note that, at both of these nurseries, there was a heavy fall of rain shortly after the applications of chloropicrin. This in all probability partially sealed the chloropicrin in the soil and slowed down the rate of dispersal of the chemical. For some unaccountable reason formalin had a very harmful effect on seedling yields at Newton.

At most nurseries the interval of thirty days between injection and sowing generally produced a higher yield of seedlings than did the shorter time intervals.

The differences in the weeding times between treatments was generally small, and not significant at the 1 per cent level for significance. However at Inchnacardoch, where the weedcrop was particularly heavy and where a better appreciation of the efficacy of the sterilizers could be ascertained, it was quite clear that the weed-killing properties of chloropicrin increase with higher concentrations, and that chloropicrin at one gallon per hundred square yards is roughly equivalent to formalin at ten gallons per hundred square yards.

In general, the time interval between the date of application of the sterilizers and the date of sowing had little effect on weeding time.

The 1955 Extension of the 1954 Experiment

After removing the 1954 crop of first year Sitka spruce seedlings, four of the experiments were given a basal dressing of phosphate and potash fertilizers, and were re-sown with Sitka spruce.

Assessments of mean heights at the end of the growing season showed that the sterilization treatments had no significant residual effects at one nursery, but at the other three nurseries there were significant increases in heights on plots which were treated with the higher concentrations of chloropicrin in the first year. The residual effect of formalin was generally slightly less than the two higher rates of chloropicrin (see Table 51). No treatment had any significant effect on seedling yields.

The 1955 Experiment

In 1955 it was decided that the most economic, and at the same time effective, dosage rate for chloropicrin was somewhere in the region of 0.42 to 0.84 gallons per hundred square yards (twenty to forty gallons per acre). For these reasons a simpler experiment was laid down at five nurseries in which chloropicrin applied at 0.31, 0.62 and 0.93 gallons per hundred square yards (fifteen, thirty or forty-five gallons per acre) was compared with five gallons of formalin diluted with one hundred and fifty gallons of water per hundred square yards. The sterilizers were applied either in late October (autumn) mid-December (winter) or thirty days before sowing (spring). The experimental design was a four-by-three factorial, with four replications.

From Table 52 it will be seen that at three out of the five nurseries the two higher rates of chloropicrin (0.62 and 0.93 gallons per hundred square yards) produced a highly significant increase in seedling heights when compared with formalin. At the remaining two nurseries, Fleet and Bush, the differences in seedling heights were not significant. Furthermore it was shown that both autumn and winter applications produced highly significant increases in seedling

Table 51

Heights of 1+0 *Sitka Spruce Seedlings raised in* 1955, *on soil treated with various concentrations of Chloropicrin or Formalin in* 1954

Treatments Gallons per 100 square yards	Mean heights in ins. Inchnacardoch	Newton	Fleet	Wykeham
Chloropicrin 0.21	1.85	1.42	2.15	1.07
„ 0.52	1.76	1.63	2.14	1.18
„ 0.84	1.79	1.75	2.24	1.56
„ 1.14	1.95	1.97	2.25	1.47
„ 1.45	2.01	2.03	2.45	1.60
Formalin 10.0	1.90	2.10	2.02	1.40
S.E. ±	0.10	0.07	0.04	0.08
Critical Difference 5%	Not	0.20	0.10	0.22
Critical Difference 1%	sigt.	0.28	0.20	0.30
No. of days before sowing				
10	1.98	1.83	2.26	1.34
20	1.97	1.84	2.23	1.39
30	1.73	1.79	2.14	1.41
S.E. ±	0.07	0.04	—	0.06
Critical Difference 5%	0.19	Not	Not	Not
Critical Difference 1%	Not sigt.	sigt.	sigt.	sigt.

heights at two out of the five nurseries; at a third nursery the autumn application was significantly better than either the winter or spring treatments. At the remaining two nurseries, the time of application of sterilizers had no significant effects on seedling heights. A separate statistical analysis of the data for each period of application has been included as Table 53. From these full data some anomalies arose which are inexplicable; for instance, the better effects of winter applications of formalin compared with chloropicrin, at Bush and Newton, when the reverse was true with spring applications.

There were no significant differences in seedling yields between the four main sterilizer treatments at any of the nurseries, and only at Bush were yield differences caused by the date of application of sterilizers. At this nursery spring applications caused a significant reduction in seedling numbers.

Discussion

From the data on mean heights and total numbers of seedlings, presented in Tables 48, 50 and 52, and from data from unsterilized plots sown alongside the 1954 and 1955 experiments (data not presented), the percentage of usable seedlings (over 1½ inches tall) can be expressed using the tables prepared by Jeffers (1955). Such an expression shows that from nine experiments the percentage of usable seedlings in unsterilized plots was approximately fifteen per cent, as compared with approximately sixty-six per cent usable from fourteen experiments in which chloropicrin was applied at between thirty and forty gallons per acre. Formalin averaged approximately fifty-six per cent usable seedlings. The mean total stocking of seedlings was approximately eight hundred and fifty per

Table 52

Heights and Numbers of 1 +0 *Sitka spruce seedlings raised in* 1955 *on soil treated with Chloropicrin or Formalin applied in the Autumn, Winter or Spring before sowing*

Treatments Gallons per 100 square yards	Mean Height in inches					Total Numbers per Sq. Yd.				
	Inchna-cardoch	New-ton	Fleet	Bush	Wyke-ham	Inchna-cardoch	New-ton	Fleet	Bush	Wyke-ham
Sterilization										
Chloropicrin 0.31	3.16	2.98	2.10	1.98	1.84	893	838	360	771	1137
„ 0.62	3.80	3.32	2.30	2.18	2.05	899	841	365	780	1173
„ 0.93	3.86	3.31	2.41	2.47	2.16	904	828	346	677	1147
Formalin 5	3.17	2.10	2.20	2.59	1.56	890	900	374	703	1139
S.E. ±	0.99	0.06	0.08	0.06	0.04	33	27	21	37	34
Critical Difference 5%	0.32	0.18	Not	0.18	0.13	Not	Not	Not	Not	Not
Critical Difference 1%	0.43	0.24	sigt.	0.24	0.17	sigt.	sigt.	sigt.	sigt.	sigt.
Time of Application										
Autumn	3.42	3.08	2.20	2.35	2.00	914	815	341	757	1181
Winter....	3.62	3.03	2.23	2.41	1.83	899	885	364	785	1152
Spring	3.46	2.67	2.33	2.16	1.87	885	849	379	657	1114
S.E. ±	0.855	0.06	0.07	0.06	0.04	38	23	17	32	30
Critical Difference 5%	Not	0.14	Not	0.16	0.11	Not	Not	Not	Not	Not
Critical Difference 1%	sigt.	0.19	sigt.	0.21	—	sigt.	sigt.	sigt.	sigt.	sigt.

square yard on soil treated with chloropicrin at thirty to forty gallons per acre, of which approximately five hundred and seventy were usable. With formalin approximately five hundred and sixty seedlings were usable out of a total of 1,000 seedlings per square yard. In the control plots, one hundred and seventy were usable out of approximately 1,200 per square yard. Thus the overall effects of chloropicrin in these experiments were very similar to formalin as far as the production of usable seedlings was concerned. It must be remembered however that the chloropicrin yields were reduced in some experiments on account of an inadequate time lapse between the date of application and the date of sowing. In practice, with a time interval of more than thirty days, a higher yield of seedlings would be expected.

The best results were usually obtained on the lighter nursery soils e.g. at Inchnacardoch, Newton and Fleet. On heavier silty and clay type of soils e.g. at Bush, Tulliallan and Wykeham, the chloropicrin applications have been less effective. This is to be expected from a sterilizer which depends for maximum efficiency upon its vapour readily permeating the pore spaces of the soil. Formalin on the other hand depends upon its high solubility in water, and the saturation of the soil by the solution, for efficient spread and soil contact.

It is interesting to note that American writers on chloropicrin soil sterilization stress the importance of having soil temperatures of at least 50°F for effective sterilization of medium loams, and 60°F for heavy soils (McLellan, Christie and Horn, 1949). Such temperatures are, of course, unobtainable out of doors in Scotland during February and March, and it was therefore somewhat surprising to note the very satisfactory results obtained when soil temperatures at a depth of four inches in the experiments were as low as 38°F. The temperatures varied according to the date of application of the chloropicrin and the nursery. A time lapse of seven to ten days between injection and sowing is common in America whereas a *minimum* of thirty days was required in Scotland. The longer period necessary in Scotland was no doubt due to the lower soil temperatures.

From the 1955 experiments it appears that autumn applications would be the most suitable in practice, providing of course that seedbed areas are vacant and a fairly fine soil tilth can be obtained. This would also permit early seed sowing in spring. When chloropicrin is applied less than thirty days before sowing, germination is seriously inhibited and final yields of seedlings are reduced. This is particularly so with rates above 0.84 gallons per hundred square yards. Formalin on the other hand does not cause such a depression in either the yield, or on the speed of germination, when applied even ten days before sowing.

Sitka spruce seed is usually slow to germinate and takes from fourteen to thirty days. Other species on the other hand can germinate in seven days and therefore would probably require a longer period than thirty days between the date of injection and sowing.

There is little to choose between chloropicrin and formalin as far as weed control properties are concerned; both showed some weed control effects but these were generally so slight and inconsistent to be of no practical importance.

Of the two chemicals, chloropicrin was applied far more quickly than formalin and for large scale use can be easily applied by machine.

Conclusions

Chloropicrin applied by injection into nursery seedbeds at a depth of four inches, and at the rate of 0.62 gallons to 0.84 gallons per hundred square yards (thirty to forty gallons per acre), is usually a more effective soil sterilizer (gauged by the height growth of seedlings) than formalin solution applied at five to ten gallons of thirty-five per cent formalin, diluted in one hundred and fifty gallons of water per hundred square yards.

Chloropicrin should be applied *at least* thirty days before sowing, but *preferably in the previous autumn.* Sowing seed within thirty days of the date of application of the chemical results in a pronounced reduction in the speed of germination, and may seriously reduce both the final yield and heights of seedlings. Formalin does not require such a long time lapse, ten to twenty days is quite adequate between date of application and sowing the seed.

Applications of chloropicrin to light sandy and medium-textured soils are more successful than applications made on heavy silty loams and clay loams, although some response to sterilization is obtainable on the heavier soil types.

Brief Notes on the Practical Application of Chloropicrin to Nursery Practice

Chloropicrin can easily be applied to seedbeds with the aid of machinery, and already a modified tractor-mounted gravity-feed constant-head type of injector (see Plate 4) has been successfully used for sterilizing large areas of seedbeds in several nurseries. This machine is fitted with four injector tines each of which feeds a constant stream of chloropicrin into the soil at the required depth. The rate of injection is governed either by the speed of the tractor or by the jet size in the feeder lines.

It has been estimated that one man and a tractor-mounted injector could sterilize from six to eight acres (net) of seedbed per day.

Table 53

Heights and Numbers of First Year Sitka spruce seedlings raised in 1955 *on soil treated with Chloropicrin or Formalin applied in the Autumn, Winter or Spring before sowing*

Treatments Gallons per 100 square yards	Mean Height in inches					Total Numbers per Sq. Yd.				
	Inchna-cardoch	New-ton	Fleet	Bush	Wyke-ham	Inchna-cardoch	New-ton	Fleet	Bush	Wyke-ham
Autumn										
Chloropicrin 0.31	2.88	3.09	1.98	2.03	1.98	879	813	332	784	1182
„ 0.62	3.73	3.35	2.32	2.27	2.17	958	752	347	878	1244
„ 0.93	3.82	3.52	2.35	2.57	2.22	936	824	321	708	1183
Formalin 5	3.23	2.37	2.15	2.53	1.61	887	871	362	658	1181
S.E. ±	1.48	0.14	0.08	0.10	0.06	68	58	32	46	36
Critical Difference 5%	0.52	0.44	0.27	0.30	0.20	Not sigt.	Not sigt.	Not sigt.	148	Not sigt.
Critical Difference 1%	0.75	0.63	—	—	0.29				—	
Winter										
Chloropicrin 0.31	3.43	3.02	2.03	1.92	1.72	972	896	350	793	1094
„ 0.62	3.78	3.44	2.43	2.25	1.94	857	870	404	780	1107
„ 0.93	4.02	3.26	2.26	2.43	2.07	917	895	363	765	1218
Formalin 5	3.24	2.39	2.19	3.05	1.60	820	877	304	801	1173
S.E. ±	1.66	0.11	0.12	0.13	0.10	61	32	29	80	43
Critical Difference 5%	Not sigt.	Not sigt.	Not sigt.	0.42	0.34	Not sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.
Critical Difference 1%				0.60	—					
Spring										
Chloropicrin 0.31	3.18	2.82	2.29	1.98	1.80	832	806	397	737	1118
„ 0.62	3.88	3.16	2.15	2.03	2.04	883	900	346	684	1168
„ 0.93	3.74	3.16	2.62	2.42	2.20	860	806	356	558	1040
Formalin 5	3.03	1.55	2.25	2.20	1.45	963	923	417	650	1131
S.E. ±	1.99	0.13	0.18	0.10	0.06	54	50	44	44	63
Critical Difference 5%	Not sigt.	0.48	Not sigt.	0.32	0.20	Not Sigt.	Not sigt.	Not sigt.	Not sigt.	Not sigt.
Critical Difference 1%		0.58		0.46	0.29					

The cost of treating one square yard of seedbed with chloropicrin at thirty gallons per acre by machine is tenpence per square yard in 1957, or approximately one shilling and sevenpence per thousand usable seedlings.

BIBLIOGRAPHY

EDWARDS, M. V., 1952. *The Effects of Partial Soil Sterilization with formalin on the raising of Sitka spruce and other conifer seedlings.* Forest Record 16. For. Comm. Lond.

JEFFERS, J. N. R., 1955. Relationship between the percentage of usable conifer seedlings and the mean height of seedlings as assessed at stocktaking. *Rep. For. Res.* 1953/54. For. Comm. Lond.

LINDGREN, R. M. and BIRCH, W. H., 1949. *Plant Diseases Reporter* 33, (5) p. 228-31.

MAKI, T. E. and BIRCH, W. H., 1951. *Root-rot Control and Soil Improvement at the Ashe Forest Nursery.* Occasional Pap. 119. U.S.F.S. South For. Expt. Stn.

MCCLELLAN, W. D., CHRISTIE, J. R. and HORN, N. L., 1949. Efficacy of soil fumigation affected by soil temperature and moisture. *Phytopath* 39 p. 272-83.

ROARK, R. C., 1934. *A bibliography of Chloropicrin.* 1848-1932. U.S. Dept. of Agriculture. Misc. Pub. 176.

SMITH, N. R., 1939. The partial sterilization of soil by chloropicrin. *Proc. Soil. Sci. Soc. Amer.* (1938).

APPENDIX I

List of Main Experimental Projects and the Localities where Work is Concentrated

While most of the investigations and experiments of the Research Branch are scattered throughout forests all over the country, there are certain areas where work on some projects is more or less concentrated. These are briefly given below:

NURSERY EXPERIMENTS. Including partial sterilization of the soil, maintenance of fertility, compost and fertilizer experiments, green cropping, chemical weed control, etc.

Inchnacardoch Forest Nursery, near Fort Augustus (Inverness-shire)
Newton Nursery, near Elgin (Morayshire)
Benmore Forest Nursery, near Dunoon (Argyll)
Tulliallan Nursery, (Fife) near Alloa
Bush Nursery, near Edinburgh
Fleet Forest Nursery, Gatehouse of Fleet (Kirkcudbrightshire)
Kennington Nursery, near Oxford
Sugar Hill Nursery, near Wareham (Dorset)

PLANTING EXPERIMENTS ON PEAT

Kielder Forest (Northumberland)
Clocaenog Forest (Denbighshire)
Beddgelert Forest (Caernarvonshire)
Inchnacardoch Forest (Inverness-shire)
Achnashellach Forest (Ross-shire)

PLANTING EXPERIMENTS ON HEATHLAND

Croft Pascoe Forest (Cornwall)
Wareham Forest (Dorset)
Wykeham and Broxa in Allerston and Langdale Forests (Yorks)
Harwood Dale in Langdale Forest (Yorkshire)
Teindland Forest (Morayshire)
Clashindarroch Forest (Aberdeenshire)

PLANTING EXPERIMENTS ON SAND DUNES

Newborough Forest (Anglesey)

PLANTING EXPERIMENTS ON CHALK DOWNLAND

Queen Elizabeth Forest (Buriton, Hants and Sussex)
Friston Forest (Sussex)

ESTABLISHMENT OF OAK

Forest of Dean (Gloucester, Hereford and Monmouth)
Dymock (Gloucester and Hereford)

POPLAR TRIALS AND SILVICULTURAL EXPERIMENTS

Harling, Thetford Forest (Norfolk)
Yardley Chase (Beds. and Northants.)
Quantock Forest (Somerset)
Forest of Dean (Gloucester)
Hockham, Thetford Forest (Norfolk)
Wynyard (Durham)
Cannock (Stafford)
Doncaster (Yorkshire)
Dyfnant (Montgomeryshire)
Blandford (Dorset)
Stenton (East Lothian)

SPECIES PLOTS

Bedgebury Forest (Kent)
Thetford Chase (Norfolk)
Beddgelert Forest (Caernarvonshire)
Benmore Forest (Argyll)

GENETICS WORK: Grafting, propagating, etc.

Alice Holt Forest (Hants.)
Grizedale Forest (Lancashire)
Bush Nursery (near Edinburgh)

EXPERIMENTAL SEED ORCHARDS

Rendlesham Forest (Suffolk)
Newton Nursery (Morayshire)
Whittinghame Estate (East Lothian)
Ledmore Nursery (Perthshire)
Bradon Forest (Wiltshire)

TREE BANKS (National Collections of Plus Trees)

Newton Nursery (Morayshire)
Bush Nursery (Midlothian)

PATHOLOGICAL RESEARCH AREAS

Moorburnhead (Dumfriess-shire)	Group dying of Conifers
Glenfinart (Argyll)	Group dying of Conifers
Haldon (Devon)	Resin bleeding of Douglas fir.
Harling, Thetford (Norfolk)	Fomes annosus
Mundford, Thetford (Norfolk)	Bacterial canker of poplar
Queen Elizabeth Forest (Hampshire)	Wound Protectants

ARBORETA

Bedgebury Pinetum (Kent)
Westonbirt Arboretum (Gloucestershire)
Crarae, near Minard (Argyll)

APPENDIX II

Staff of Research Branch as at 31st March, 1957

DIRECTORATE OF RESEARCH AND EDUCATION. 25, Savile Row, London, W.1. Tel.: Regent 0221.

J. Macdonald, C.B.E., F.R.S.E.	Director
Miss A. Brooks, M.B.E.	Senior Executive Officer

FOREST RESEARCH STATION. Alice Holt Lodge, Wrecclesham, Farnham, Surrey. Tel.: Bentley 2255.

M. V. Laurie, O.B.E., M.A., Dip.For.	Conservator, Chief Research Officer
R. Rendle	Higher Executive Officer

MACHINERY

R. G. Shaw, B.A., A.M.I.Mech.E.	Machinery Research Officer

UTILISATION DEVELOPMENT

E. G. Richards, M.C., B.Sc.	Divisional Officer
C. D. Begley, B.Sc.	District Officer
J. R. Aaron, M.A.	,, ,,

SILVICULTURIST (SOUTH) (Alice Holt).

R. F. Wood, B.A., B.Sc.	Divisional Officer
M. Nimmo	District Officer
G. D. Holmes, B.Sc.	,, ,,
J. R. Aldhous, B.A.	,, ,,
A. D. S. Miller, B.Sc.	,, ,,
J. Jobling, B.Sc.	,, ,,
J. M. B. Brown, B.Sc., Dip.For.	,, ,,
W. H. Hinson, B.Sc., Ph.D.	Scientific Officer
G. Buszewicz, Mgr.Ing.	Experimental Officer

SILVICULTURIST (NORTH). Government Building, Bankhead Avenue, Sighthill, Edinburgh, 11. Tel.: Craiglockhart 4010.

M. V. Edwards, M.A.	Divisional Officer
G. G. Stewart, B.Sc.	District Officer
R. Faulkner, B.Sc.	,, ,,
R. Lines, B.Sc.	,, ,,
D. W. Henman, B.Sc.	,, ,,

MANAGEMENT

F. C. Hummel, M.A., D.Phil.	Divisional Officer
A. M. Mackenzie (Edinburgh)	District Officer
G. M. L. Locke, B.Sc.	,, ,,
A. J. Grayson, M.A.	,, ,,
D. Johnston, B.A.	,, ,,

STATISTICS

J. N. R. Jeffers, A.I.S. . .	Senior Scientific Officer

FOREST PATHOLOGY

T. R. Peace, M.A.	Divisional Officer
J. S. Murray, B.Sc.	District Officer
S. Batko, D.Ing.	

FOREST ENTOMOLOGY

M. Crooke, B.Sc., Ph.D.	District Officer
D. Bevan, B.Sc. .	,, ,,
Miss J. Davies, B.Sc. .	Experimental Officer

FOREST GENETICS

J. D. Matthews, B.Sc. .	District Officer
A. F. Mitchell, B.A., B.Ag. .	,, ,,

DOCUMENTATION AND PHOTOGRAPHY

G. D. Kitchingman, M.A., Dip.For.	District Officer
I. A. Anderson	Principal Photographer
Miss T. K. Wood . . .	Photographer

APPENDIX III

List of Publications

The following papers by members of the Research Branch staff were published during the year ended 31st March, 1957:

Aldhous, J. R.	Experiments in Forest Nurseries with some recently developed Weed Killers. *Weed Control Conference Proceedings, British,* 1956.
Begley, C. D.	*Growth and Yield of Sweet Chestnut Coppice.* Forest Record No. 30.
Crooke, M. and Kirkland, R. C.	The Gale of 1953: an Appraisal of its Influence on Forest Pest Populations in Pine Areas. *Scot. For.* Vol. 10. No. 3, pp. 135-145, July 1956.
Edwards, M. V.	The design, lay-out and control of provenance experiments. *Zeit. für Forstgenet. u. Forstpflanz* 1956.5 (5-6), p. 169-190.
”	Third Report of an Investigation into Various Races of European larch. *Report on Forest Research* 1956. pp. 142-153.
Faulkner, R.	Note on current and recent forest nursery research in Scotland. *Arbor.* Sept. 1956.
”	Effects of different methods of storing seedlings from Heathland Nurseries. *Rep. For. Research* (1956) H.M.S.O. pp. 113-123.
”	Effects of seedbed compaction on germination and yield of S.S. seedlings. *Rep. For. Research* (1956) H.M.S.O. pp. 123-131.
Gray, W. G.	Starting a Small Forest Tree Nursery. *Agriculture* Vol. LXIII. No. 5, 6. 1956.
Green, R. G. and Wood, R. F.	Manuring of Conifer Seedlings planted directly in the Forest. *Rep. For. Research.* March 56. pp. 132-137.
Holmes, G. D.	Experiments on the Chemical Control of *Rhododendron ponticum. Proc. Brit. Weed Cont. Conf.* 1956.
Holmes, G. D., Miller A. D., and Shaw, R. G.	Methods of Scrub Clearance. *Agric. Review* 3 (1957). pp. 31-36.
Holmes, G. D. and Buszewicz, G.	Preliminary Trials of a Quick Method for Estimating the Seed Content of Cones. *Rep. For. Res.* 1956. pp. 98-106.
”	A summary of Five Years' Experience of Seed Testing for Larch Species. *Rep. For. Res.* 1956. pp. 106-113.

Hummel, F. C.	Rapid Determination of Increment in Great Britain. *I.U.F.R.O., 12th Congress, Oxford* (1956)*: Papers.*
,,	Proposals for the Collection and Publication of Information on Instruments used in Forestry. *I.U.F.R.O., 12th Congress, Oxford* (1956)*: Papers.*
,,	A note on the Improvement of Abnormal Age Class Distribution. *I.U.F.R.O., 12th Congress, Oxford* (1956)*: Papers.*
,,	*Tariff Tables for Conifers in Great Britain.* Forest. Record No. 31. H.M.S.O.
Laurie, M. V.	Current trends in Forest Research. *The Advancement of Science* No. 51. 1956. pp. 178-188.
,,	The Effect of Forests in Water Catchment Areas on the Water Losses by Evaporation or Transpiration. *Empire Forest Review*, Vol. 36, No. 1. pp. 55-58.
Matthews, J. D.	The Improvement of Forest Trees by Selection and Breeding. *Biology and Human Affairs.* 21.3.56.
,,	Breeding Improved Forest Trees. *Agricultural Review* 2 (1956), 39-41.
,,	The Survey of Seed Sources and Plus Trees in Britain. *International Union of Forest Research Organisation, 12th Congress, Oxford* 1956. ***Papers.***
Murray, J. S. and Young, C. W. T.	The effect of Brashing and Thinning Debris on the incidence of *Lophodermium pinastri. Quart. Journ. Forestry.* Vol. 1, January 1956.
Peace, T. R.	Approach and Perspective in Forest Pathology. *Forestry,* Vol. XXX 1957.
Stewart, G. G. (with Somerville, H. C.)	A note on a High Elevation Wood in Midlothian. *Scot. For.* 11(1) pp. 23-5.

In addition, members of the Research Branch staff assisted in the compilation of the following Forestry Commission publications:

Crooke, M.	*Pine Shoot Moth.* Leaflet 40.
Jobling, J.	*The Quality of Poplar Plants.* Leaflet 39.
Low, J. D.	*Fomes annosus*, a Fungus Causing Butt Rot and Death of Conifers. Revision of Leaflet 5.
Murray, J. S.	*Oak Mildew.* Leaflet 38.
Nimmo, M.	*Traps for Grey Squirrels.* Free pamphlet.
Richards, E. G.	*Utilisation of Hazel Coppice.* Bulletin 27.

FORESTRY COMMISSION

REPORT
ON FOREST RESEARCH
for the year ended
March, 1958

LONDON
HER MAJESTY'S STATIONERY OFFICE
1959

ADVISORY COMMITTEE ON FOREST RESEARCH

Membership as at March, 1958

Chairman

The Earl of RADNOR, K.C.V.O.
Chairman, Forestry Commission.

Members

Professor Sir HARRY G. CHAMPION, C.I.E., D.SC., M.A.,
Department of Forestry, Imperial Forestry Institute, South Parks Road, Oxford.

Dr. W. J. HALL, C.M.G., M.C., D.SC.,
Commonwealth Institute of Entomology, British Museum (Natural History), 56, Queens Gate, London, S.W.7.

Dr. F. Y. HENDERSON, C.B.E., D.SC., D.I.C.,
Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks.

G. V. JACKS, Esq., M.A.,
Commonwealth Bureau of Soil Science, Rothamsted Experimental Station, Harpenden, Herts.

Sir EDWARD SALISBURY, C.B.E., D.SC., F.R.S.,
Craindene, Strandway, Felpham, Bognor Regis, Sussex.

Professor H. M. STEVEN, M.A., PH.D., F.R.S.E.,
Department of Forestry, University of Aberdeen, Old Aberdeen.

Sir WILLIAM G. OGG, M.A., PH.D., LL.D.,
Rothamsted Experimental Station, Harpenden, Herts.

Dr. J. W. GREGOR, PH.D., D.SC., F.L.S.,
Scottish Society for Research in Plant Breeding, Scottish Plant Breeding Station, Pentlandfield, Roslin, Midlothian.

Professor W. H. PEARSALL, D.SC., F.R.S.,
University College of London, London, W.C.1.

Secretary

Mr. RUSSELL RENDLE,
Forest Research Station, Forestry Commission, Alice Holt Lodge, Wrecclesham, Farnham, Surrey.

CONTENTS

PART III

REPORTS ON RESULTS OF INDIVIDUAL INVESTIGATIONS

APPENDICES

INTRODUCTION

By JAMES MACDONALD

Director of Research and Education

Good progress has been made towards the completion of the new building at Alice Holt Lodge and it is hoped that it will be ready for occupation by the spring of 1959. Work has been completed on the main structure.

There are few changes in staff to record. Dr. Crooke returned from Canada after his stay in that country as a Nuffield Foundation Fellow. Mr. H. Cruickshank, District Officer formerly in the Education Branch, joined the Library staff.

Visitors to Alice Holt were not quite so numerous as in the previous year but, in all, they numbered 411. In addition to visitors from this country, there were visitors from Austria, Australia, Belgium, British Guiana, British Honduras, Burma, Canada, Chile, Cyprus, Denmark, Finland, Eire, Germany, Ghana, India, Iran, Italy, Kenya, Malaya, the Netherlands, New Zealand, Norway, Nyasaland, Pakistan, Sierra Leone, South Africa, Sudan, Sweden, Tanganyika, Turkey, United States of America and the Union of Soviet Socialist Republics.

A meeting of forest tree breeders was held at Alice Holt in July 1957, under the auspices of the International Union of Forest Research Organisations. It was presided over by Dr. C. Syrach Larsen of Denmark. Students from the Imperial Forestry Institute, Oxford and from the Universities of Edinburgh, Aberdeen and Wales paid their annual visit to the Research Station while, among others who came, were parties from the Surrey Branch of the Royal Forestry Society of England and Wales and the Frensham Heights Summer School.

Experimental areas in Scotland were visited by Mr. Erskine Childers, Minister of Lands in Eire, who was accompanied by a party of officials. Other areas in the north were seen by parties of students from Norway, from Aberdeen and from Bangor. Experiments in forests in north-eastern England were visited by students from the Botany Department of Manchester University and by schoolchildren from Yorkshire.

The Director and Mr. C. D. Begley travelled to Australia and New Zealand as delegates to the 7th British Commonwealth Forestry Conference and, on his way home, the Director visited forest research establishments in Thailand and Turkey. He also presided over a meeting of the Permanent Committee of the International Union of Forest Research Organisations which was held at Badenweiler in Germany. At the request of the Government of Cyprus, Mr. J. N. R. Jeffers visited that country to advise on the design of experimental work.

Colonel R. G. Shaw and Mr. E. G. Richards attended the second session of the F.A.O./E.C.E. Joint Committee on Forest Working Techniques and the Training of Forest Workers which was held in Moscow in September 1957.

Mr. Richards also attended a meeting of the E.C.E. Timber Commission in Geneva and the 9th Session of the European Forestry Commission of F.A.O. which was held in Rome. Colonel Shaw also acted as a delegate at a meeting of the Study Group on the Testing of Forest Machinery and the Testing of Forest Tractors, held in Geneva in March 1958.

Mr. T. R. Peace attended the meeting of the International Poplar Commission and the Congress in Paris in April 1957 and Mr. J. D. Matthews represented the International Union of Forest Research Organisations at a meeting, in London, of the International Commission for the Nomenclature of Cultivated Plants. Mr. D. R. Johnston attended the course given by the Imperial Forestry Institute on Forest Management and Messrs. Laurie, Wood, Edwards and Hummel were present at the meeting of the British Association in Dublin.

Various members of the Research Staff lectured at courses conducted by the Commission at Northerwood House in the New Forest and at the short courses for woodmen held at Chatsworth.

The Advisory Committee on Forest Research held its annual meeting at Aldeburgh, Suffolk in July 1957 when members were able to inspect experimental work in the nearby forests of Rendlesham and Tunstall. No meeting of the Nursery Nutrition Committee was held during the year.

The Advisory Committee on the Utilisation of Home-Grown Timber met twice during the year, once in London and once in Chester when they visited the works of Messrs. J. R. Gordon & Co. at Queensferry and also saw work in progress in the Commission's Forests.

The informal Joint Committee with the Nature Conservancy met at the Conservancy's station at Furzebrook in Dorset when various research matters of interest to both departments were discussed. Close liaison was maintained with the Forest Products Research Laboratory at Princes Risborough and an informal joint committee, meeting frequently, has been set up to co-ordinate the work on the programme of research into the properties of home-grown timbers which has been agreed between the Commission and the Department of Scientific and Industrial Research. As work on this programme develops, the knowledge which will accumulate will be of the greatest value in the utilisation and marketing of forest produce.

Close co-operation has been maintained during the year with the Imperial Forestry Institute at Oxford and with the Rothamsted Experimental Station and the Macaulay Institute for Soil Research at Aberdeen.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE

Chief Research Officer

The Season

1957 was one of those years which demonstrate very nicely that many interesting features are lost if only annual averages are considered.

The total rainfall was only slightly below normal, yet April was one of the driest ever recorded and, for England and Wales, only 19 per cent of the average fell; while at several stations dry records of around 110 years standing were broken. In Scotland, however, only the Eastern coastal districts had less than 50 per cent of the normal for that month. Had it not been for the mild, wet weather from January to March the effect of this April drought would no doubt have been far worse that it actually was.

Sunshine was only about 2 per cent above average for the year but June was a wonderful month—the sunniest for 75 years at both Glasgow and Kew—and with 143 per cent of the average for England and Wales as a whole. Heat waves were experienced during mid-June and again during the last few days and into the first week of July. At Camden Square, London, the thermometer rose to 96°F—the highest temperature in June since 1858. These periods of high temperature, occurring when they did, should give us a good seed year in 1958 for many tree species.

July and August were well below average for sunshine though both started with a few hot days. December, on the other hand, was the sunniest since 1929.

On the whole the year was remarkably free from damaging late spring frosts and there were no exceptionally severe gales though some local damage was done in Scotland on April 18th and October 31st and in England and Wales on April 25–26th and November 3–4th.

January 1958 was a wet month more because of the number of days on which rain fell than because of a very high total—in fact in many places the total was around the average. On January 28th 1·89 inches of rain fell in 24 hours at Kennington Nursery—a remarkable fall for this rather dry district. From January 20th–25th there was a cold snap with snow and frost, but otherwise there was little hard weather until the following month.

The rainfall for February was decidedly above normal being 150 per cent of the average for England and Wales and 115 per cent for Scotland.

Snowstorms occurred from the 7th–9th and from 23rd–25th—heavy in Scotland, North England and parts of the Midlands but only moderate or slight in the South. There were severe gales in Scotland about the 3rd week in the month.

March brought severe drought and in parts of Southern England there were 23 days with a total of less than $\frac{1}{10}$ inch of rain. Early in the month cold easterly winds were common and there were some snowshowers. Ground frosts were very numerous but only a few were severe.

PART I

This part of the Report deals with current work carried out by the various sections of the Forestry Commission's Research Branch. Only the more important items of work are mentioned in this summary.

Forest Tree Seed Investigations

GERMINATION TESTING. The routine testing of seed took up about 80 per cent the time of the seed laboratory. Work on the improvement and standardisation of seed testing methods, particularly for seeds that are difficult to get to germinate, was continued.

SEED STORAGE. Long term seed storage trials for six of the commoner conifer species were concluded at the end of seven years storage. All species had deteriorated seriously after two years storage in sacks in a cool room. With the exception of the larches very little drop in germinative capacity occurred after seven years storage of dried seed in sealed containers at a temperature of 2°C., and it is clear that this is a satisfactory method of long-term storage for most conifer seeds. In the case of the larches, the seed lots tested started with a low germination figure. In sack storage the seed went bad in a year, while in sealed tins at 2°C. their germinative capacity was reasonably well maintained for two to three years, but the seed was at a higher than normal moisture content when the tests started.

Nursery Investigations

In nursery manuring experiments using larger than normal dressings of nitrogen, phosphorus and potassium fertilisers on *Tsuga* seedbeds, only extra nitrogen had any appreciable effect on the growth of the seedlings. Comparisons between Urea and "Nitrochalk" as nitrogen manures showed that there was no advantage in using urea in place of "Nitrochalk". Trials with heavy and late dressings of nitrogen on seedbeds again failed to cause increased susceptibility to early autumn frosts in Douglas fir and Japanese larch. Frost damage was similar in manured and unmanured beds, and the formation of terminal buds was not affected by the manuring.

Long term fertility experiments were continued at Teindland and Newton nurseries in Scotland, and at Wareham and Bramshill in England. At Teindland repeated treatment with combined fertilisers and hopwaste produced the tallest seedlings, followed closely by artificial fertilisers alone. Hopwaste alone gave relatively poor results this year. At Bramshill, by contrast, the bracken/hopwaste compost treatments were best, followed by combined compost and fertilisers, while fertilisers applied alone have for the last two years produced smaller seedlings. At Wareham, Dr. Rayner's compost regimes continued to produce good plants though growth was below average, and the plots treated with hopwaste compost (without bracken) showed symptoms of potassium deficiency. The Newton nursery long-term experiment was all under seedbeds this year. Growth was very poor owing to the season, and results will be assessed next year on the second year seedlings.

Information on "Dunemann" beds throughout the country was collected and trial beds laid down.

Special studies on the techniques for raising silver firs, *Abies* spp., were continued. The best results were obtained by chilling the seed for 24 hours with water at 2°F. before sowing, but stratification for 4 weeks before sowing at the beginning of April also gave good results. Early sowing of unstratified seed in January, February or early March also gave satisfactory results.

Autumn sowings of oak gave as good results as spring sowings, but beech sown in the autumn did not always do as well. The addition of an extra three inches of soil over the winter, as a protection against birds and rodents, had little effect on seedling production; its efficacy as a protection was not however adequately tested. Corsican pine was shown to benefit from later sowing (early-mid-April) than Sitka spruce (late March) or *Tsuga heterophylla* (early March).

Spray irrigation during the dry spring greatly increased the yield of usable seedlings of Sitka spruce, *Tsuga heterophylla*, *Abies procera*, and *Thuja plicata*, but had no effect on Corsican pine, Japanese larch, birch, beech or oak seedlings. Later irrigation during the summer, which was wet, did not yield further benefit.

The nursery stage of seedling undercutting experiments is almost concluded, and the evaluation of this technique as an alternative to transplanting will depend on the results of planting experiments of undercut seedlings, and of normal transplants, in the forest.

Chemical methods of weed control in nurseries continued to be investigated. A wide range of substances was tested but so far nothing has been found that is as cheap or as selective as the mineral oils. Demonstrations of the current recommendations for the use of mineral oils for post-emergence and inter-row transplant spraying were successfully carried out in several Conservancy nurseries.

Hand weeding at intervals of six weeks was found to involve nearly twice as much labour as weeding at intervals of two or four weeks. There was no difference between the latter owing to a dry start to the season, but in a wet season one would expect the four-week interval to be more laborious and costly than the two-week interval.

Initial trials with seed dressings to control seed-borne diseases and pre-emergent damping off gave negative results. Attacks by cutworms (larvae of Noctuid moths) were successfully controlled by application of Dieldrin or Aldrin at 100 c.c. per 100 square yards (1 gallon per acre).

PLANT HANDLING. Plants tolerated storage in polythene bags for periods of two weeks up to six months, according to species and the condition of the plants at time of lifting. Plants lifted while dormant stored better than plants lifted while flushing. It is also important in some species that the foliage be dry when the plants are bagged. Spruces were outstanding in their ability to survive long periods of storage. *Abies procera* seedlings showed the least toleration of this method of storage, of any species.

It was shown that, under moderately drying conditions (though not sunny or warm) seedlings began to lose their power of survival on transplanting after only two hours exposure of the roots. Six hours exposure resulted in nearly 100 per cent casualties. Six hours exposure in damp still conditions did no harm. The species tested were Corsican pine, Douglas fir and Lawson cypress.

Silvicultural Investigations in the Forest—South and Central England and Wales

AFFORESTATION OF PARTICULAR TYPES OF LAND. The experiments on the Lizard peninsula on soils derived from Serpentine rock have now been going for five years. *Pinus radiata* is outstandingly the most successful and vigorous species tested, and good results have also been obtained with lodgepole pine of coastal provenance and Sitka spruce. Heavy applications of phosphate at the time of planting are necessary for the best results. On dry compacted mineral soils on the hills in mid-Wales, planting trials of many species have, so far, shown that the easiest species to establish are *Abies nobilis*, Sitka spruce, lodgepole pine, and the hybrid *Cupressocyparis leylandii*. All exhibit striking growth responses to phosphate applied at planting.

IMPROVEMENT OF CHECKED PLANTATIONS. Following on the striking responses to phosphate manuring on a number of checked plantations in the south, large-scale mechanical broadcasting of triple superphosphate, at rates up to six hundredweight per acre, has been carried out, to evaluate the practicability and the economics of such treatments. Removal of heather using a 2-4D spray was successfully achieved but did not, of itself, result in appreciable recovery of the tree crops. The effects of added phosphate were however greater on such cleared areas.

NUTRITION OF POLE CROPS. This long-term project was continued in the form of complex factorial tests of rates of application of nitrogen, phosphorus, potassium, calcium, magnesium and trace elements. Growth responses will be correlated with needle analyses to detect the nutrient uptake by the trees. In respect of nitrogen it has been found that salts of weak acids appear to be more efficiently absorbed by organic matter in the soil than salts of strong acids, such as nitrates or sulphates, which are rapidly leached out of the soil.

DERELICT WOODLAND INVESTIGATION. Active experimentation on this project has ceased for the time being. A full account of the investigations to date is in an advanced state of preparation.

CHEMICAL WEED CONTROL. Initial control of vegetation on fire traces can be obtained better by the use of 2,4-D/2,4,5-T mixtures, T.C.A. or "Dalapon" than by such substances as sodium chlorate, arsenicals, monuron or borax compounds, though the maintenance of a weed-free condition once cleared can be achieved with relatively low rates of application of the latter substances. The economics of chemical clearance are being studied.

Chemical control of grass in newly-planted areas is being investigated. The main compounds under test being "dalapon" and amino-triazol. Work on the control of woody growth continued.

PROTECTION OF SEEDS AND TREES AGAINST DAMAGE BY ANIMALS. Protection of seeds sown direct in the forest by patch spraying with bitumen emulsion was again shown to be effective and practicable. It is, however, more costly than protection by seed dressing, on which further work is required. Endrin and Toxaphene show promise for the control of vole plagues. Tests have been continued on the use of repellents for protecting young trees from gnawing by voles and other animals.

GIBBERELLIC ACID. Of a large number of species tested, the only one which showed marked increases in growth was beech.

CHEMICAL FIRE RETARDANTS. Preliminary tests with sodium calcium borate and mono-ammonium phosphate for fireproofing vegetation have yielded promising results.

Silvicultural Investigations in the Forest—Scotland and North England

REPLANTING AREAS OF RECENTLY CLEARED CONIFERS. A beginning has been made to finding answers to some of the questions commonly asked, such as the following:

"If ground preparation was used for the first crop, what work, if any, of this nature must be repeated?"

"How can inadequate drainage be improved?"

"Which more exacting species can now be grown?"

"How much time, if any, should elapse before replanting, to avoid weed competition?"

Control of deer is also one of the chief problems, and this too is being investigated.

AFFORESTATION PROBLEMS. Trials of a double-mouldboard tine plough have been carried out successfully. Pure crops of lodgepole pine, hitherto normally used only in mixture, have been established; studies of peat shrinkage after ploughing and afforestation have been commenced. Work on deep acid peat and on smoke polluted sites has continued.

AGE AND TYPE OF PLANT. The hypothesis that the sturdiness of a plant is of more critical importance than its age or type, and that sturdiness is best measured by root collar diameter, is being studied in detail.

MANURING IN THE FOREST. Some completed early trials have been written off, and new experiments have been begun on older crops which have formed canopy on poor peat when nutrient deficiencies are indicated.

HIGH ELEVATION, AND OTHER WOODS ON EXPOSED SITES. A more detailed survey of such woods than has been possible in the past, has been commenced.

THINNING. The early results of a comparative trial of heavy crown and moderately heavy low thinning are given.

Provenance Studies

Certain of the older lodgepole pine experiments are now beginning to give information on yields. Some observations are made on the Albertan provenance, which in the more difficult environments now seems likely to prove disappointing. The combining factors of seed size and quality in provenance work are exemplified in one experiment. New provenance experiments with lodgepole pine have been laid down in Central Wales and South-west England, where such enquiries have previously been neglected.

The growth of Polish larch in Britain is briefly reviewed on the basis of somewhat scanty experience. Preliminary performance of the younger experiments, and the results from a few older stands, suggest that Polish larch is very suitable for use in Britain, especially on the more exacting sites. Stem form has however been rather disappointing.

One of the older Sitka spruce experiments has been the subject of an investigation into the density of timber. This experiment suggests that considerably greater yields may be obtained with more southerly provenances on suitable sites.

Sitka spruce provenance experiments in the north have shown highly significant differences in the percentages of trees with dead leaders following frost damage. There is a clear relationship between the damage and the occurrence of trees with

Lammas shoots, these being much more frequent in the Washington provenances than in those from the Queen Charlotte Islands. The possibility of using Washington or other southern seed sources for non-frosty localities is discussed.

A small study of the provenance attributes of the Japanese cedar, *Cryptomeria japonica*, has been commenced.

Poplars

The planting and maintenance of varietal trial plots and silvicultural experiments has proceeded as in previous years. Trial plots were laid down at five sites and experiments at three others. Assessments have been started in many older plots and this work will be extended gradually to plots planted more than six years ago. Planting of the populetum has continued and work on bacterial canker has again been undertaken. Nearly 30,000 cuttings of poplar were distributed during the winter to persons concerned with its cultivation.

Forest Ecology

Work has concentrated on the study of Corsican pine in Britain, mainly in an attempt to define the conditions which limit its healthy growth. The Ecologist has also been concerned in soil classification studies in connection with Working Plan soil surveys. His studies on the factors affecting the survival of beech regeneration in the Chilterns have been continued.

Forest Soils

A large number of soil and foliar analyses for major nutrients was done on samples from the various research sections. Over 1,200 foliage samples from forest manuring trials were received for analysis. A study of the leaching of nitrogen fertilisers from forest soils suggests that losses may be reduced if hydroxides or salts of weak acids are substituted for neutral salts. Work has started on the main long-term project of the nutrient relations of forest crops and forest sites.

Forest Genetics

The progress made in building up a collection of material for breeding work is briefly summarised. The total number of Plus and Other trees of all species which have been marked and recorded is 2,462. The larches, Douglas fir and beech together account for one half, and Scots pine for one quarter, of this total.

Just over half of the selected trees (i.e. 1,359 trees) have been propagated vegetatively and one third (816 clones) are now established in Tree Banks.

Propagation by grafting was continued at Alice Holt, Grizedale and Bush Nurseries. 7,834 grafts were attempted and the overall success was 78 per cent.

The planting of seed orchards continued and work was done at sixteen sites totalling 174 acres. The summary of the present position shows that 103½ acres have been planted or are in an advanced state of formation. There are thirty-eight acres of Scots pine seed orchard, and thirty-two acres of seed orchard have been planted for the production of the first generation hybrid larch, *Larix* X *eurolepis*.

A useful advance in the technique of propagation by cuttings is afforded by the "mist" propagation unit installed in a heated frame at Alice Holt in June 1957. This was used for the propagation of X *Cupressocyparis leylandii* and the combination of treatment of these cuttings with Seradix 3 and a rooting medium of half peat and sand gave 55 per cent success three months after insertion.

Twenty-two delegates, representing thirteen countries, attended a four-day meeting of Forest Tree Breeders at Alice Holt in July 1957. This was held under the auspices of Section 22 of the International Union of Forest Research Organisations.

Forest Pathology

The main work was on the butt rot fungus *Fomes annosus*. Surveys of the incidence of the disease were started in all Conservancies in England and Wales, and protection by stump treatment recommended where necessary. Trials of a wide range of protectants have been laid down. Information on other butt-rot fungi is being collected at the same time.

Serious losses were caused in nurseries this year by *Lophodermium pinastri*. Spraying experiments showed that *Botrytis cinerea* can be controlled in nursery beds by a wide variety of fungicides, provided the sprays are applied before infection takes place. A scheme for controlling outbreaks of Keithia disease, *Didymascella thujina*, on *Thuja* by rotating the cultivation of this species round different nurseries, so as to leave them free from *Thuja* plants for at least two years, has been started.

An infection plot, for testing the susceptibility of various pines to attack by *Melampsora pinitorqua*, has been successfully established, and further additions were made to the *Ribes-Pinus* infection plot for testing resistance of five-needled pines to the rust fungus *Cronartium ribicola*.

A new disease has appeared on Scots pine at Wareham. The fungus closely resembles, but is not identical with, *Septoria acicola*, which causes "brown spot" disease on *Pinus palustris* in the Southern States of America.

Forest Entomology

Much of the section's activity was concerned with studies on the pine looper moth, *Bupalus piniarius* L. The countrywide pupal survey revealed low levels of population in almost all forests, with slightly higher than normal but not immediately threatening, counts only at Tentsmuir and Rendlesham. A further season's detailed sampling was carried out on the sample plot at Elveden, Thetford, and various investigations on the parasites of the pine looper were made. In August some 360 acres at Tentsmuir Forest were treated with a D.D.T. fog emitted by a T.I.F.A. (Todd Insecticidal Fog Applicator) machine. This treatment resulted in good control of the high pine looper population.

Investigations on *Semasia diniana* Guen. were continued, the main interest being centred on the biology of the species and, particularly, on the host tree preferences exhibited by it. Further work on this topic will almost certainly be restricted by shortage of material since the population has "collapsed". Bacterial disease, predators, parasites, and intrinsic degeneration all seem to be involved in this reduction in numbers.

The biennial survey of larch sawfly numbers was again carried out, and in general low levels of population of the three main species *Pristiphora erichsoni* Htg., *P. laricis* Htg., and *Anoplonyx destructor* Bens. were recorded. Biological studies on the group of conifer feeding sawflies were continued in the laboratory.

Experimental work on the insecticidal protection of young conifer crops against *Hylobius abietis* L. was completed during the year under review. Further observations and minor tests are being continued in user trial areas.

Two trials with "Swingfog", a light and portable insecticidal fog generator, were conducted during the year, one against *Semasia diniana* and the other against *Anaplonyx destructor*. Both gave disappointing results but further tests are being planned.

Studies of Growth and Yield

Provisional yield tables for oak and beech have been published, and work has started on a yield table for the noble silver fir, *Abies nobilis*. Yield tables for different thinning grades are under compilation for some of our more extensively planted conifer crops, and the preparation of "stand tables", showing the distribution of tree girths in crops of a given mean girth, has been started. Methods of forecasting increment in crops which may have started abnormally slowly are under investigation. There was a net increase of 41 permanent sample plots bringing the total to 767. Most of the new plots were established in stands of the less common conifers. Eleven batches of timber were supplied to the Forest Products Laboratory for testing, and a special investigation on the strength of pit props is also in progress, supplies for which were arranged by the Management Section.

Census of Woodlands

170,000 acres were re-surveyed, completing the counties of Cumberland, Westmorland and Devon. A revised assessment of the area, standing volume and increment of the woodlands in Great Britain was made. The total area is now 4 million acres approximately, covering 7·1 per cent of the land area of the country (as compared with 6·4 per cent in 1947). The area of Forestry Commission plantations has doubled in the last ten years. Unproductive woodland has decreased by 160,000 acres, but there still are 1,210,000 acres (30 per cent of the total) of this type, indicating the magnitude of the problem of rehabilitation which still faces us. On account of the large amount of planting in the last ten years, the age-class distribution is more unbalanced than ever, but this should right itself in time. Future census work will be on a sampling basis, which will greatly reduce the field work.

Working Plans

The Working Plan section has been very active in working out the techniques and procedures for collecting and presenting the information required for working plans. Special attention has been given to survey work, stock mapping and soil classification and mapping, methods of estimating increment, etc. In order to test procedures in practice, working plan surveys were carried out in a number of forests of differing types.

Forest Economics

The Forest Economist spent the year under training at Oxford, during which time a number of economic problems in forestry were studied.

Design and Analysis of Experiments

Most of the work of the Statistics Section has been devoted to advising all Sections of the Research Branch on the design of their experiments and sample surveys, and to the analysis and reporting of the experiments and surveys completed. Reorganisation of the Section to deal more rapidly with the current statistical work of the Research Branch has been necessary, and the main bulk of the computing is being transferred to electronic computers. Programmes are being written for the standard analysis of variance, for multiple regression, and for multivariate analysis.

Besides the routine work of design and analysis, investigations have been made into the problem of sampling timber from forest crops in order to determine the physical, mechanical, and chemical properties of the timber. Research is also continuing into the analysis of experiments on perennial crops by methods which describe the continuing growth of the trees as a growth curve, and into the application of multivariate analysis to problems of forest research.

The Section has co-operated with the Working Party of Section 25 of the International Union of Forest Research Organisations on the standardisation of measurements, and the collection and publication of information on instruments used in forestry.

Machinery Research

The number of machines suitable for forest operations continued to expand. A few nurseries are now completely mechanised and many more have been mechanised in varying degrees. British-made power saws have made progress in the improvement of their power-to-weight ratio, and a new pendulum cross cut saw has been introduced for small forest conversion depots.

One recent development has been the increase in the scope of the tractor-mounted scrub clearing machines, partly due to the introduction of the tractor live-power take-off.

New winches have been introduced which greatly increase the logging capabilities of the multi-purpose medium tractor.

Utilisation Development

Following the satisfactory performance of the two-roomed office built from thinnings, plans are being made to erect a three-bedroomed dwelling house from thinnings of Scots pine, Sitka spruce, and Japanese larch. Investigations are in progress on the strength of home-grown softwood pit props, both seasoned and unseasoned, on the durability of fence posts treated with different preservatives, on the tannin content of conifer barks, the yields of hardwood coppice, the moisture content of fresh felled Sitka spruce, and on the rate of seasoning in the forest of poles felled at different seasons, with and without the removal of bark after felling. Results are given of an investigation into the extra man-hours of work required in harvesting Sitka spruce bark, as compared with ordinary peeling without harvesting the bark.

PART II

This part consists of reports of progress made by workers attached to universities and other institutions. The subjects covered are usually of a more fundamental nature and much of the work is assisted by grants from the Forestry Commission.

Researches on Mycorrhiza

Dr. Ida Levisohn, working at Bedford College, University of London, has shown that, in inoculation experiments, the introduction of a mycorrhizal fungus, *Boletus scaber*, which had been observed to produce stimulation of birch seedlings in various soils, was found to depress the development of young birches growing in a certain soil from Yorkshire. Analysis of pot-culture experiments showed that, through the rhizosphere activity of the inoculated mycelium which was accompanied by delay in mycorrhiza-formation, the unprotected root systems of the experimental plants were exposed to attacks by a parasitic mycelium present in the soil.

In the laboratory, studies have concentrated on various ecological groups of fungi active in forest soils. Chemical methods employed in classifying certain types of fungi proved suitable for classifying sterile fungi of interest, isolated from root associations and from certain " difficult " soils.

Soil Mycology: Mycostasis in Soils

At the University College of North Wales, Bangor, Dr. C. G. Dobbs and Dr. Joan Bywater have continued their study of the inhibition of fungal germination and growth on forest and other soils, and have demonstrated a pronounced seasonal variation in this phenomenon during the year. Germination of spores of *Mucor ramannianus* was completely inhibited on all soils tested during the summer months of 1957, but not so during the winter when soils were found to vary widely in this respect, some supporting growth and sporulation of the test fungus. Several forest soils which inhibited spore germination were found to stimulate growth after freezing, but this effect was not obtained with surface litters or with marine sands.

In respect of the effect of adding glucose, two categories of soils were distinguished:

1. the large majority in which addition of glucose results in appreciable growth of the test fungus; and
2. those few in which it does not.

These last included several strongly calcareous soils and sands, and one surface sample of low pH from Gore Heath near Wareham, Dorset.

The mycelial growth of eleven common basidiomycetes and one wood-rotting ascomycete was found to be markedly reduced when they were grown on agar discs separated by cellulose film from a range of forest soils. Percentage reduction in diameter growth for different fungi varied from 51 to 98, with an average of 84 per cent.

Effects of Tree Growth on the Soil

Dr. T. W. Wright at the Macaulay Institute for Soil Research, Aberdeen, has continued his researches on the nutrition of tree crops on sand dunes, deep peat and other soils.

At Culbin Forest, the small height response to phosphate has been maintained, and a considerable response to nitrogen applied in 1956 has been observed. On these sandy soils, early summer rainfall strongly influences height growth.

Laboratory work on the moisture content—pF relationship in peat suggests that moisture shortage may limit growth on shallow peat areas, although this stage has not yet been reached in the experimental area at the Lon Mor.

Soluble N, K, and Mg fertilizers applied to lodgepole pine and Sitka spruce on the deep peat have depressed growth in the first growing season. Aqueous ammonia, calcium cyanamide, and granite dust are being tried as slow-acting sources of N and K.

At Wauchope Forest, monthly samples are being taken for determination of moisture and NH_3-nitrogen in plough ridges on deep peat, where depth of ridge has been found to influence tree growth.

Needle samples taken from 20-year old Norway spruce in East Conservancy (Scotland) show that major nutrient content varies with locality, but is not related to the nutrient content of the A_1 horizon. Needle nitrogen shows a strong correlation with height growth in Quality Classes II–IV.

Foliage samples have been taken from existing fertilizer experiments to determine possible optimum nutrient levels.

Soil Faunal Investigations

Dr. P. W. Murphy, working at the Rothamsted Experimental Station, Harpenden, continued his investigations into the mesofauna of forest soils. Marking of leaves in beech litter with the radioactive isotope Tantalum 182 was found to be useful for locating leaves a year later and assessing their rate of disappearance. Data was obtained, in a laboratory study, on the tolerance of Orobatid mites to periods of low humidity at different temperature. Cultures of a number of species of mites have been maintained and their feeding habits studied. It was found that one species, *Fuscozetes fuscipes* Koch, feeds readily on insect larvae. This was surprising as Orobatid mites are generally considered to be detrital or fungal feeders.

Physiology of Flowering in Trees

Dr. Wareing and Mr. K. A. Longman, working in the Department of Botany, Manchester University, demonstrated that in Japanese larch, flowering in young trees could be greatly stimulated by training branches in a downward direction. The growth of trees and the initiation of flowering were also accelerated by increasing day-length conditions. By continuous exposure to long-day conditions in a greenhouse, seedling birch was grown to a height of 9 feet in 12 months from sowing, and started producing male catkins when only 13 months old.

Research on Keithia disease, Didymascella thujina

Mr. R. G. Pawsey concluded his work on this disease at the Botany Department, Nottingham University. The results will be published shortly. During the year, extensive inoculation experiments were carried out in controlled temperature conditions at 5°C., 13°C., and 20°C. At 20°C., the incubation period of infection varied from fourteen to nineteen days. The incubation period was approximately six weeks at 13°C. No development took place at 5°C.

It was shown that ascospores on *Thuja* foliage could survive five months at 5°C. Temperature was found to be a major factor in the development of the apothecia.

Early stages of infection were studied and haustoria were observed and described for the first time.

Larch canker

Dr. J. G. Manners of the Botany Department, Southampton University has continued his work on the relationship between larch canker and *Trichoscyphella willkommii.*

Preliminary experiments on the persistence of cankers on European larch, produced by inoculation with this fungus, have shown that repeated freezing may reactivate dormant cankers, and thus be of importance in relation to the persistence of cankers. Experiments on the effects of the presence of the fungus on areas of larch stem damaged by local freezing are still in progress: an interim assessment indicates that frost-induced cankers normally heal within two years, but that if inoculated with a spore suspension of the fungus at the time of freezing, they may develop and persist for longer periods.

A Hirst spore trap has been obtained and spore trapping in cankered larch plantations will be carried out in the winter of 1958–59.

Studies on Meria laricis

Mr. P. Biggs has continued his researches into the biology of the larch leaf-cast fungus, *Meria laricis*, at the Botany Department, Southampton University. A more detailed examination of the fungus in culture was made. Spore germination experiments indicate that *Meria* will only germinate within a narrow range of high humidities. Growth of *Meria* in shake culture is enhanced by the addition of sterile larch needle extract. Correlation of data from Forestry Commission nurseries with weather information from the Meteorological Office has shown a definite relationship between temperature and humidity prior to the appearance of a noticeable *Meria* attack.

Shelterbelt Research

Mr. R. Neil Parker, working at the Department of Forestry, Edinburgh University, reports that, as in the previous year, the main effort has been concerned with silvicultural rather than with microclimatic studies. However, some anemometric work has been done, and investigations into the assessment of exposure using unhemmed flags have continued and show considerable promise.

Experimental planting and treatment of belts, and planned management of shelterbelt systems, is progressing; contacts with landowners who may be willing to co-operate have been maintained.

A final format for description of shelterbelts in the field has been developed. Descriptions are filed in the office on a specially devised punched-card system to assist in classification and provide easy reference.

The scope of the project was widened by a visit to the Moray Firth district where the rather special conditions were studied, and useful contacts made.

Soil Fauna

Mr. Gifford, also working in the Department of Forestry, Edinburgh University, has made a start on a comparison of the fauna of open moorland soils and that of a Sitka spruce plantation 30 years old, established on the same type of site. Little specific difference has so far appeared, but there appear to be changes in the relative abundance of different species. Present work is aimed at defining changes and seeking reasons for them, for which the necessary apparatus has been constructed.

PART III

In this section of the report, the results of certain investigations carried out by the Forestry Commission Research Branch are reported in the form of short articles. The main points of interest are summarised below.

Use of Triple Superphosphate for Forest Manuring

Mr. M. V. Edwards reports the results of experiments in which triple superphosphate was compared with ground mineral phosphate in 21 manurial trials in newly formed plantations of lodgepole and Scots pines, Sitka spruce and Japanese larch, in two years and over a wide range of sites in northern Britain. One and a half ounces of mineral phosphate is normally used in establishing plantations on poor sites, and one third of this amount of triple superphosphate was used. Mineral phosphate is applied by placing or throwing it around the stem of the plant, and the same method was found suitable for triple superphosphate. Various special methods of application of triple superphosphate, devised in order to obviate the risk of killing the plant by direct application, were tested and found unnecessary. In some of the experiments there were small significant differences, sometimes in favour of one and sometimes of the other material, but in general no consistent differences were found, either at survival or height growth, up to an age of three years, with all species at all sites.

Drain Deepening in the Border Forests

The results of two experiments in deepening drains from six or nine inches to twenty-four inches in Sitka spruce forests on *Molinia* peat overlying clay are described by G. G. Stewart. In one case, the deepened drains had scarcely any effect on the water table between the drains over four years observations, while in the other a reduction of water level of about five inches was achieved. In neither case was there any significant effect on the growth of the trees, in either height or girth.

Seed Orchard for Producing Hybrid Larch Seed

A. F. Mitchell gives an account of the establishment of a seed orchard at Newton, Morayshire in which three selected parents of European and twelve of Japanese larch were established as grafts in 1951 to 1953. The composition and lay-out of the orchard are described. Lessons learnt are:

(1) That establishment is slow when grafts are moved to a site. It would have been better to have done the grafting directly on to rootstocks planted in their final positions.

(2) It is better to plant at twice the final density so that more flowers are available for testing in the first years of flowering and early yields of seed are increased.

(3) The temperature in mid-July seems to be critical at Newton for the following year's cone production.

(4) Unless aided by treatments designed to stimulate flowering, cone production is likely to be erratic from year to year. The total yield of cones in 1956, an exceptionally good year for coning, was 12,550 cones, on 11 clones out of 15, and in 1958 only 346 on 4 clones out of 15. (The total area is 4 acres containing 786 grafts.)

Patterns of flowering show marked protogyny, especially in European larch, the mass of pollen production coming after the female flowers have ceased to be receptive. European larch flowers later than does Japanese larch, so that the pollen of the latter is abundant when the female flowers of the former are receptive. Consequently, if free pollination is relied on, cones on the European larch grafts will contain mainly hybrid seed, while those on the Japanese larch will contain nearly all Japanese larch seed. A programme of controlled crossing was carried out in which thirty-one of the possible hybrid combinations were made, twenty-one of them reciprocally. The progeny are under test, and already in the first year show marked differences in vigour and colour.

Experiments on the Use of Toxaphene and Endrin for the Control of Short-tailed Voles

The results of preliminary trials of "Endrin" and "Toxaphene" as poison for controlling short-tailed voles are described by G. D. Holmes. First trials in 1956 at two forests indicated reductions in vole number on treated areas, but plot sizes were inadequate to give conclusive results. The main trial in 1957 was carried out on two-acre unit plots, and results show generally high levels of control with "Endrin" at 0·3 lb. and "Toxaphene" at 2·25 lb. per acre. The costs of materials were approximately £1 per acre, the total costs with mechanical spray application being in the region of £2 10s. 0d. per acre. The toxicity hazards to domestic animals, wild birds and animals other than voles are not fully known, and practical applications are not recommended until these hazards can be assessed in more extensive trials.

Comparison of Methods of Sampling for Green Moisture Content

Results of a statistical study of the reliability of different methods of sampling trees, for determining the green moisture content of the timber, are described by R. S. Howell and D. Kemp, and provide information on the bias and variability of four different sampling procedures, as a guide for large scale investigations.

Loss of Weight of Small-sized Hardwoods on Drying

E. G. Richards, Utilisation Development Officer, reports the results of investigations into the rate of drying of small-sized hardwoods in the forest. Unpeeled logs stacked in piles under shade in the spring are found to lose weight by up to five per cent after one month, and up to twenty per cent by the end of the summer, but different species varied considerably. Ash lost only 4 per cent, oak 7 per cent, birch 11 per cent, beech, sweet chestnut, sycamore and elm 14·22 per cent. If stacked in open clearings, slightly greater losses in weight were experienced.

Investigation into Three Races of European Larch

Mr. M. V. Edwards describes the early forest stages of a provenance experiment with Alpine (Münsterthal, Switzerland), Sudeten (Silesia) and Scottish (Darnaway, Morayshire) origins of European larch. Replicated planting experiments were put down in two forests, growth being much faster at one than the other. Differences in heights due to nursery origin persisted for twenty-two years at the slow-growing site and for seventeen years at the faster-growing site. The height growth of the Münsterthal origin was less than the other two, and the crop was much less uniform. Phenological observations indicated that Münsterthal plants flushed earlier in the spring than Sudeten or Darnaway plants. The stem form of the Darnaway is the best. The experiments in both localities were subject to die-back in the canopy-forming stage; the Münsterthal provenance suffered worst at the poorer site and was the only provenance to suffer at the better site. The Sudeten and Darnaway plots were more uniformly resistant to canker caused by *Trichoscyphella* (*Dasyscypha*) *willkommii* than were the Münsterthal ones, though individual trees in the latter were resistant. It is concluded that, though Münsterthal may be adequately resistant on the most favourable frost-free larch sites, the risk of frost is generally too great to allow for the use of this or other Alpine origins. Sudeten and certain tested Scottish origins are resistant under quite severe conditions, where they are able to produce satisfactory crops.

PART I

Reports of Work carried out by Forestry Commission Research Staff

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES and G. BUSZEWICZ

Routine Work

Seed Testing 232.31

The major part of the work of the Alice Holt Seed Testing Laboratory continued to be routine testing of the Commission's seed. This service function took up about 80 per cent of the available laboratory time during the year ending March 1958. In this period, 610 seed samples were received for analysis, on which the following tests were completed:

Purity analyses:	519
Germination tests:	1,062
Tetrazolium tests	103
Seed Moisture tests:	234
Cone tests:	31

These numbers include 196 germination tests and 210 seed moisture tests carried out as part of the experimental work described below. All tests for declarations under the Seeds Act (1920), were carried out in accordance with the International Rules for Seed Testing which are officially recognised as a guide in the United Kingdom.

The only major addition to the equipment of the Seed Laboratory was an infra-red moisture meter, which will be used as a means of speeding up seed moisture tests over the conventional oven methods.

Seed Storage 232.315.2

Storage and despatch of seed for the Research Branch sowing programme is part of the function of the Seed Laboratory. This includes a yearly total of about 250 lb. seed, and involved preparation of about 5,000 measured and packeted lots. A considerable amount of time was spent assisting in the planning, equipping and organisation of the Commission's new central refrigerated seed store now nearing completion at Alice Holt.

Research Work

Seed Testing Methods 232.318

The improvement and standardisation of seed testing methods is inevitably a major subject of investigation in any seed laboratory. This is especially necessary in the case of forest tree seeds as many species are difficult to germinate, and existing rules give rather inadequate guidance for many important species.

The main effort during the year was concentrated on work connected with the revision of the Rules of the International Seed Testing Association relating to forest seeds. This is being done through the Forest Seeds Committee of the I.S.T.A., comprising ten members representing nine countries. The final proposals for revision should be completed in Autumn 1958.

In addition to the above, co-operation in the programme of the Biochemical Test Committee of the I.S.T.A. was continued.

Seed Storage and Longevity

A great deal of time was spent in examining all available literature on the subject of storage of tree seeds for a general review which will be published in *Forestry Abstracts*, Vol. 19(3) and (4).

Table 1

Germinative Capacity of Pine, Spruce, Larch and Birch Seeds during Seven Years of Storage

Germinative Capacity

Species	Storage method	Seed Moisture content % (wet wt.)		Years of Storage							
		Initial	Final	0	1	2	3	4	5	6	7
Scots pine	Sack, unheated room	10·6	11·7	94	79	33	8	3	0	—	—
	Dry, sealed, unheated room	4·7	7·9	94	94	89	84	90	85	—	—
	Dry, sealed 2°C. ..	5·4	7·0	94	97	96	96	97	95	—	—
Corsican pine	Sack, unheated room	11·5	10·4	71	35	19	5	1	0	—	—
	Dry, sealed, unheated room	9·1	9·9	71	63	58	47	17	6	—	—
	Dry, sealed 2°C. ..	8·9	9·5	71	66	63	59	63	58	58	54
Sitka spruce	Sack, unheated room	—	10·7	72	23	2	0	—	—	—	—
	Dry, sealed, unheated room	8·0	8·7	72	76	69	74	52	29	22	0
	Dry, sealed 2°C. ..	8·1	9·0	72	75	78	80	72	66	64	60
Norway spruce	Sack, unheated room	12·4	10·2	82	74	54	20	3	—	—	—
	Dry, sealed, unheated room	9·6	9·0	82	83	84	79	63	59	50	32
	Dry, sealed 2°C. ..	9·5	9·2	82	84	91	85	73	80	78	81
European larch	Sack, unheated room	15·0	13·3	18	1	0	—	—	—	—	—
	Dry, sealed, unheated room	11·0	11·5	18	14	13	12	1	0	—	—
	Dry, sealed 2°C. ..	11·3	12·1	18	15	13	16	10	5	7	2
Japanese larch	Sack, unheated room	15·3	13·3	32	7	2	0	—	—	—	—
	Dry, sealed, unheated room	13·5	12·0	32	25	6	7	0	—	—	—
	Dry, sealed 2°C. ..	14·4	12·3	32	17	25	16	10	5	6	6
Birch (*Betula pendula*)	Sack, unheated room			Not tested							
	Dry, sealed, unheated room	—	—	27	21	20	16	0	—	—	—
	Dry, sealed 2°C. ..	—	—	27	20	22	24	19	17	11	16

Seed storage trials started in 1950 with Scots pine, Corsican pine, European larch, Japanese larch, Norway spruce, Sitka spruce, and birch, were concluded after seven years as all the original seed was finally utilised in germination checks. The results are summarised in Table 1 opposite.

Dry, sealed storage at a constant low temperature (2°C.), was superior to other methods tested, for storage of all species for periods exceeding one or two years. Under these conditions, the pines retained full viability for five years, and Sitka spruce and Norway spruce showed negligible change after four years and seven years, respectively. Both larch species deteriorated after two to three years, almost certainly because of the relatively high moisture content at which the seed was sealed.

Seed storage in sacks in an unheated room gave poor results, all species showing serious deterioration after less than one year. Dry, sealed storage in an unheated room was markedly superior to storage in sacks, and was adequate for storing spruces, Corsican pine and birch for two to three years, and for Scots pine up to four years. These observations confirm the importance of seed moisture content and temperature in seed storage, control of both these factors at a low level being necessary for prolonged retention of viability. Maintaining a low moisture content without temperature control is adequate for a time, but for storage periods over two years a constant low temperature is necessary.

A small experiment was also completed to determine the rate of seed deterioration when stored in paper envelopes in a centrally heated room. This is the normal method of short-term storage for seed samples awaiting germination analysis and it is important to know the rate at which germination capacity declines under these conditions. The results for three species are presented in Fig. 1 below:

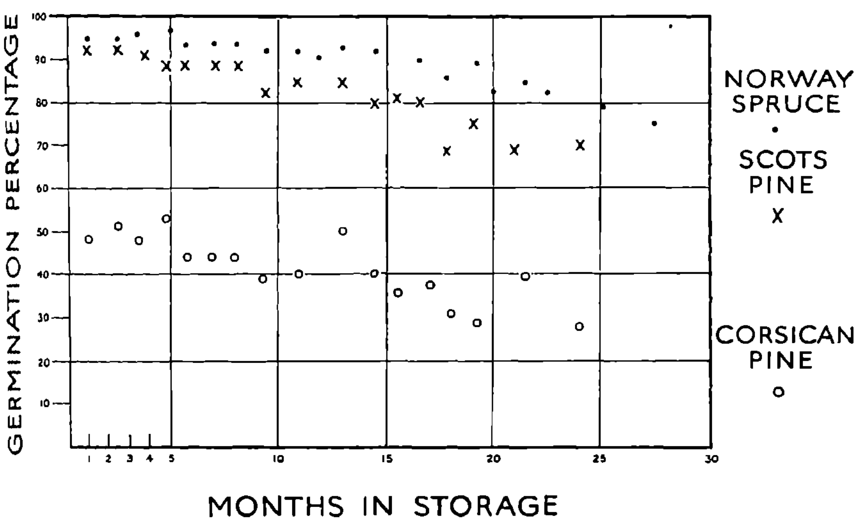


FIG. 1. Germinative Quality of Seeds Stored in Unsealed Paper Packets in a Heated Room.

These results indicate a slow steady drop in seed quality over the two years storage period for all three species. Germination loss is negligible for the first few months and it is evident that samples of these species for germination test can be safely stored in this way for periods of two months, which is the maximum necessary in practice. It is interesting to compare these results with those reported in Table 1, page 18. If sealed containers are not used it is evident that storage in a centrally heated room is more efficient than exposing seed to the fluctuating temperature and humidity of an unheated room. The average equilibrium seed moisture content throughout the seed packet storage test was Scots pine—6·2 per cent, Corsican pine—7·0 per cent, and Norway spruce—6·6 per cent, all considerably lower and less variable than the equilibrium levels under the unheated room conditions.

Seed storage tests were started during the year for *Abies grandis*, *A. nobilis*, *A. concolor*, *Thuja plicata*, Lawson cypress and Douglas fir.

The investigations of the long-term storage requirements of beechnuts, as outlined in the last report, were continued into their second year. A wide range of humidity and temperature conditions are being examined, but it is too early to draw precise conclusions from these tests.

Other Activities

Mr. G. D. Holmes participated in several meetings of the Committee on Transactions in Seeds regarding revision of the Seeds Acts. Also, in 1957, Mr. G. Buszewicz attended the annual seed analysts' Conference at Cambridge.

NURSERY INVESTIGATIONS

By R. FAULKNER and J. R. ALDHOUS

The amount of experimental work on nursery problems is becoming less each year and the pattern of the work is changing. Up till recently the main concentration of effort was on the use of fertilisers and on methods of partial sterilisation of the soil. Both of these subjects now play a much smaller part in the experimental programme, and work on them consists mainly of tying up loose ends. Long-term fertility maintenance, however, continues to receive attention, as also does nursery weed control. A special study is being made of nursery techniques required for the successful raising of silver firs, *Abies* spp., which often give trouble in the nursery; plant handling investigations also play a prominent part in the programme.

Experimental work was carried out in the following nurseries:

England	*Scotland*
Ampthill, Bedfordshire	Benmore, Argyll
Alice Holt, Hampshire	Bush, Midlothian
Bramshill, Hampshire	Fleet, Kirkcudbrightshire
Kennington, near Oxford	Inchnacardoch, Inverness
Roudham, Thetford Chase, Norfolk	Kirroughtree, Kirkcudbrightshire
Savernake, Wiltshire	Newton, Morayshire
Wareham, Dorset	Teindland, Morayshire
	Tulliallan, Kincardineshire

Inorganic Fertilizers

Rate of Application of Nitrogen, Potash and Phosphate Fertilizers 232.322.41

At four northern nurseries, the western hemlock, *Tsuga heterophylla*, was used as the indicator species in an experiment comparing factorial combinations of phosphorus fertilizers at normal, one and a half, and twice the normal rates; potassium fertilizers at normal, double and triple rates, and nitrogen fertilizers at normal and twice normal rates. The object of the experiment was to determine the single or combined effects of these fertilizers on seedling growth. A similar experiment has been previously described in the 1955-57 *Annual Reports on Forest Research;* Sitka spruce, Douglas fir and Japanese larch were then used as indicator species.

None of the phosphatic or potassic fertilizer treatments had any statistically significant effects on the height growth of the seedlings, but at Newton nursery the two higher rates of phosphatic fertilizers caused a highly significant reduction in the yields of seedlings.

The higher rate of application of nitrogen (0·5 oz. N per square yard), applied as "Nitrochalk", produced a slight but significant height increase to seedlings at two of the four nurseries, namely Newton and Benmore. At Inchnacardoch Heathland and at Benmore nurseries the higher rates of nitrogen caused a significant reduction in numbers.

These experiments conclude the northern work on phosphatic and potassium fertilizers which have been carried out during the period 1952-57.

Use of Urea as a Nitrogen Manure for Sitka Spruce Seedlings 232.322.41

The experiment referred to in the 1957 Annual Report was repeated in five northern nurseries. It is a factorial experiment comparing "Nitrochalk" and urea, applied at two rates equivalent to 0·25 or 0·50 oz. N per square yard, either in two halves as summer top dressings, or else with one third as a pre-sowing application followed by two separate applications of one third each in mid-summer.

At Inchnacardoch and Fleet nurseries the higher rate of application of 0·5 oz. N per square yard produced seedlings which were significantly smaller than those raised with 0·25 oz. N per square yard. At Benmore the position was reversed and the higher dosage produced a highly significant increase in seedling heights when compared with the lower dosage. At the two remaining nurseries, Newton and Tulliallan, the differences were not significant. At four of the five nurseries there were no significant differences between the urea and "Nitrochalk" treated plots; but at Newton the "Nitrochalk" treatments produced slightly taller seedlings than urea and the difference was significant at the 1 per cent level.

At four of the five nurseries, application of the fertilizers entirely as top dressings produced seedlings which were appreciably taller than seedlings raised with one-third of the dressing, applied before sowing.

No treatment had any appreciable effect on the yield of seedlings at any of the nurseries.

These results largely confirm the findings of the 1957 experiments.

It is concluded that there are no advantages to be gained by using urea in place of "Nitrochalk". Furthermore, applications of either of the two nitrogen manures entirely as top dressings in July and August are more effective than similar total dressings with one-third of the quantity applied before seed sowing. Rates of application in excess of 0·25 oz. N per square yard may sometimes be harmful. Where a gain in height growth is obtained the gain is not necessarily commensurate with the extra amount of nitrogen applied.

Rates and Times of Application of Nitrogen Fertilizers

The suggestion has been made that heavy or late applications of nitrogen fertilizers to nursery beds may produce sappy plants which do not "harden off" soon enough in the autumn, and consequently would be more liable to damage by early autumn frosts. Four years of experiments have failed to show any such tendency, but unfortunately no severe early frosts were experienced that would provide a thorough test.

Experiments were repeated in four nurseries (Kennington, Wareham, Bramshill and Ampthill) on seedbeds of Douglas fir and Japanese larch, using a wider range of rates and dates of application than previously. Each application was either at the standard rate given as a single application to most conifer seedbeds (6 lb. of "Nitrochalk" or 4 lb. of ammonium sulphate per 100 square yards according to the nursery) or at half these rates, and these dressings were applied in mid-June, mid-July, mid-August and mid-September, plots being given one, two, three or four consecutive monthly applications. Plots thus received from one-half to four times the normal application and some of the dressings went on up to two months later than usual.

At no nursery was the number of seedlings significantly reduced by application of fertilizer, though at Bramshill the numbers of seedlings on plots receiving two standard applications of nitrogen were apparently higher than on other plots. The mean height of Japanese larch seedlings increased significantly with increasing amounts of nitrogen at Wareham, Kennington and Ampthill, but was

Table 2

Effect of Nitrogen Fertilizer on Terminal Bud Formation in Japanese Larch and Douglas Fir

Treatment	Percentage Terminal Buds formed by first week of November					
	Japanese larch			Douglas fir		
	Kennington	Ampthill	Bramshill	Kennington	Ampthill	Bramshill
	%	%	%	%	%	%
Control—No Nitrogen	99	98	95	74	75	98
Nitrogen at standard rate in June and July	96	99	85	34	61	90
Nitrogen at standard rate in August and September	91	93	80	47	61	80
Nitrogen at standard rate in June, July, August and September ..	97	97	90	73	52	92

unaffected by nitrogen at Bramshill. Only at Wareham was the mean height of Douglas fir seedlings significantly greater on plots receiving the larger total amounts of nitrogen. At the three other nurseries, the height of Douglas fir seedlings was unaffected.

An early autumn frost occurred at Bramshill, where five degrees of ground frost were recorded on 30th September, but not elsewhere. A count of the number of trees frosted in each plot showed that there were no differences between treatments, though the Douglas fir seedlings were more severely damaged than the Japanese larch. Assessments of the number of terminal buds formed on plants of selected extreme treatments were made in the first week of November at Kennington, Bramshill and Ampthill, and are set out in Table 2 opposite.

It will be seen that, in all nurseries, the date of terminal bud formation in Japanese larch was not affected by the nitrogen dressings, however heavy or late. In Douglas fir the figures are less consistent but, with the exception of Ampthill nursery, nearly as many terminal buds had formed with the heaviest late dressings as in the unmanured controls.

Sterilisation, Hopwaste and Lime Applications 232.322.2 : 232.322.41

This experiment in Newton nursery was started in 1955 and is designed to compare the effects of partial soil sterilisation, lime and hopwaste applications in two of the less fertile sections (A and B in Table 3) of the nursery, which produce poor-quality seedlings. It was re-sown with Scots pine and Japanese larch in 1957. Before re-sowing, the partial sterilisation treatments were re-applied, using chloropicrin instead of formalin, and half the plots which had been previously treated with lime were re-treated using ground mineral limestone at 17·3 lb. per hundred square yards. The hopwaste treatment was also repeated using hops at 1,000 lb. per hundred square yards.

Sterilisation, as in previous years, had a pronounced beneficial effect on seedling heights of both species in both sections; hopwaste addition also had a pronounced beneficial effect on Scots pine in one section, and on Japanese larch in both sections. Lime application had a detrimental effect on the heights of Scots pine in one section but no appreciable effect on Japanese larch.

No treatment had any significant adverse or beneficial effect on the yield of Scots pine seedlings. On Japanese larch, however, hopwaste caused appreciable and significant reductions in seedling yields on both sections, and sterilization caused a slight but significant reduction in numbers in one section only. Lime applications had no beneficial or adverse effect on seedling numbers. Full data are given in Table 3.

The main conclusions to be drawn from this experiment are that, in the two particular sections of Newton nursery under investigation, hopwaste applications at 1,000 lb. per hundred square yards, and partial soil sterilisation treatments, can both appreciably increase the mean heights of Scots pine and Japanese larch, although hopwaste applications may cause a reduction in the total yield of larch seedlings. Limestone applications up to 17·3 pounds per hundred square yards are neither harmful nor beneficial to seedlings of either of the two species.

Table 3

Mean Heights and Total Numbers per Square Yard of the Third Crop of 1+0 Scots Pine and Japanese Larch Seedlings Raised by Different Treatments on Two of the Less Fertile Sections (A and B) of Newton Nursery

Expt.: Newton 6/55(FN) Extn. 57

Treatments	Scots pine				Japanese larch			
	Mean hts. (in.)		Total Nos./ sq. yd.		Mean hts. (in.)		Total Nos./ sq. yd.	
Sections	A	B	A	B	A	B	A	B
No sterilisation	1·68	1·57	732	661	1·53	1·23	668	559
Sterilisation	1·88	1·80	721	658	2·07	1·42	634	565
Standard error ±	0·04	0·02	16	16	0·08	0·05	15	10
Critical diff. 5%	0·12	0·07	Not	Not	0·24	0·14	43	Not
Critical diff. 1%	0·16	—	sigt.	sigt.	0·33	0·19	53	sigt.
No hopwaste	1·67	1·60	720	662	1·45	1·15	724	596
Hopwaste	1·89	1·70	725	656	2·15	1·50	598	529
Standard error ±	0·04	0·02	16	16	0·08	0·05	15	10
Critical diff. 5%	0·12	Not	Not	Not	0·24	0·14	43	31
Critical diff. 1%	0·16	sigt.	sigt.	sigt.	0·33	0·19	53	42
No Lime	1·79	1·77	732	686	1·87	1·34	661	547
Lime applied in 1955	1·77	1·65	722	635	1·76	1·40	665	561
Lime applied in 1955 and 1957..	1·78	1·64	725	658	1·77	1·24	657	578
Standard error ±	0·05	0·03	19	20	0·10	0·06	18	13
Critical diff. 5%	Not	0·08	Not	Not	Not	Not	Not	Not
Critical diff. 1%	sigt.	0·12	sigt.	sigt.	sigt.	sigt.	sigt.	sigt.

Long-Term Fertility Demonstrations

The long-term fertility demonstration at Teindland woodland nursery continued into the eighth year. In this trial the treatments are: no manures, artificial fertilisers only, hopwaste only and combinations of the two. Sitka spruce and lodgepole pine are used as indicator species.

As in the previous years, in the Sitka spruce section all the manuring treatments produced highly significant height increases compared with the unmanured control. Artificial fertilisers used alone produced the tallest seedlings, and these were highly significantly taller than seedlings raised on hopwaste alone. There were no significant differences between the artificial fertilisers alone and the combined artificial plus hopwaste treatments. No treatment caused any significant variation in total seedling yields.

In the lodgepole pine section, the artificial fertilisers used alone, or in combination with hopwaste treatments, produced highly significant height increases.

Hopwaste used alone caused a slight but not a significant height increase. No treatment had any appreciable effect on seedling yields.

At Elvetham nursery, Bramshill, a similar long-term experiment was continued for the seventh successive year. The mean numbers of Sitka spruce seedlings and the mean seedling heights for the various treatments are given in Table 4.

Table 4

Long-Term Fertility Trial—Bramshill Nursery
Sitka Spruce Seedlings

Treatment	Number of seedlings per square yard	Mean height (inches)
0 No fertiliser	736	0·48
F Inorganic fertiliser (Potassic superphosphate + Nitrochalk)	539	1·03
	S.E.	S.E.
C Bracken/hopwaste compost	755 ±57·0	1·77 ±0·106
FC Inorganic and organic fertilisers together	639	1·46

Seedling numbers were significantly lower on plots receiving inorganic fertiliser alone, compared with those receiving either no fertiliser or organic fertiliser alone. The mean height of seedlings was very significantly greater on all fertiliser plots than on the unfertilised control, while seedlings on plots receiving compost were very significantly taller than those on plots receiving inorganic fertiliser alone. The numbers and heights of seedlings on plots receiving both inorganic and organic fertiliser were intermediate.

This is the first year that the numbers of seedlings on plots receiving inorganic fertiliser were lower than on plots receiving compost. As regards height growth, this is the second year in which, in contrast to the Teindland experiment mentioned above, the plots manured with inorganic fertilisers have produced smaller seedlings than the compost-treated plots.

The long-term demonstration at Newton nursery, which is now in its sixth year, was resown for the second time with Sitka spruce. The crop of seedlings was particularly small, the tallest seedlings being only 0·6 inches in height. The probable reason for this was late sowing coupled with early summer drought conditions, and a rather cool and wet late summer and autumn. It is believed that the second year seedlings will give a more reliable estimate of treatment differences.

At Wareham nursery, the demonstration of the effect of two of Dr. Rayner's regimes for fertility maintenance was continued. In both regimes there is a four-phase rotation with two years of seedbeds followed by one year's summer green crop of oats, tares, and rye grass, and a winter fallow with a complete cover of bracken mulch. This is followed by one year of transplant lines.

In one regime, a compost of bracken and hops is applied, and in the other a compost of pure hops without the bracken. The composts are applied to the transplant lines at 4 cwt. per 100 square yards (10 tons per acre) and to first- and second-year seedbeds at 8 cwt. per 100 square yards (20 tons per acre).

Growth over the whole experiment was not as good as it has been in previous years; this is attributed to the dry spring which delayed the germination of many species. There were no differences between transplants under either regimes, nor between first-year seedbeds. On second-year seedbeds in the section given hops compost, seedlings of Sitka spruce showed some purple discolouration typical of slight potassium deficiency; seedlings of Corsican pine on second-year seedbeds also showed slight purpling.

Dunemann Seedbeds

The Dunemann bed, a raised seedbed composed largely of spruce litter, has attracted much interest in recent years. The method was described by W. Grant under the title "The Dunemann System of Nursery Practice" in the *Quarterly Journal of Forestry*, 46(4), 1952. It has been tried out on some scale by several private estates, and also by the Forestry Commission (particularly in North Wales). Advantages claimed for the Dunemann bed are the very high yield of seedlings of usable size obtained per pound of seed sown, more especially of certain "difficult" genera such as *Tsuga* and *Abies*, and the relative absence of weeds. High yield and low weeding costs are of course also features of the better heathland nurseries, but the Dunemann bed is a method which can be applied in districts where it is impossible to find suitable soils for the more usual type of seedbed.

Research interest in the Dunemann bed has so far been confined to inspection of the various trials of the method, and the collection of records of experiences. A bed has been laid down at Kennington nursery, but no experimental variations have so far been attempted, as it seems more profitable at this juncture to make a general appreciation of what has already been done.

Nursery Treatment of Silver Firs, Abies Species

The study of different nursery techniques to improve the quality and yields of the most commonly raised species of the *Abies* genus was continued.

Stratification of Abies Seed 232.315.3

Abies grandis was used as the indicator species in stratification experiments at Inchnacardoch, Newton and Benmore nurseries, and *Abies nobilis* was used at Tulliallan Moor, Bush and Fleet nurseries. The periods of stratification under test were 15, 25, 35 and 45 days, and these were compared with unstratified dry seed. Stratification was carried out in moist sand.

Germination was considerably speeded by stratification at two of the three nurseries where *A. grandis* was sown, and at one nursery where *A. nobilis* was sown. Where germination was hastened the speed was roughly proportional to the period of stratification, seed which had the longest period of stratification having the highest number of seedlings per unit area during the first few weeks after sowing.

At the end of the growing season, however, there were no significant differences in total numbers between any of the treatments for either species at any of the nurseries.

Stratification affected the height growth of seedlings in different ways. There were no significant differences between treated and untreated seed with *A. grandis* at Inchnacardoch or *A. nobilis* at Bush. The growth of *A. grandis* was increased in proportion to the length of stratification period at Newton, but at Benmore the converse was true, the growth of seedlings from unstratified seed being the best. Growth of *A. nobilis* at both Tulliallan and Fleet was increased by stratification, both the 35- and 45-day periods significantly increased the height growth in comparison with the control.

From these experiments it is concluded that, under the conditions experienced in 1957, stratification of *Abies grandis* or *Abies nobilis* seed for periods up to 45 days does not affect the final yield of seedlings. Stratification may cause an improvement in seedling heights with *A. nobilis*, but with *A. grandis* an increase in mean height did not occur. The experiments are to be repeated in 1958 in order to obtain more conclusive data.

At Kennington nursery, an experiment was carried out comparing the growth and yield of *Abies grandis* and *A. nobilis* seedlings from seed sown at different dates, stratified for various periods before sowing, or prechilled at 2°C. for 24 hours before sowing. Table 5 below gives the number of seedlings per square yard at the end of the season and their mean height.

Table 5

Effect of Date of Sowing, and Stratification, on Seedling Yields of Abies species

Treatment	Date of sowing	Abies grandis		Abies nobilis	
		No. of seedlings per sq. yd.	Mean height	No. of seedlings per sq. yd.	Mean height
Seed sown dry	10th Jan.	680	1·49	Not sown	Seed not available
Seed sown dry	18th Feb.	620	2·05	405	1·70
Seed sown dry	7th March	690	1·57	430	1·70
Seed sown dry	4th April	530	1·43	310	1·56
Seed sown dry	2nd May	360	1·12	210	1·18
Stratified 4 weeks	4th April	600	1·84	370	2·20
Stratified 8 weeks	4th April	420	2·01	200	1·43
Stratified 12 weeks	4th April	160	2·05	160	1·75
Pre-chilled	4th April	870	2·03	390	2·09
Differences for significance: 5%		156	0·37	98	0·15
1%		211	0·51	133	0·20

It will be seen from Table 5 that, for both species, dry seed sown in January, February or March, or seed which had been stratified for four weeks or pre-chilled, gave yields significantly better than those from later sowings or longer periods of stratification. For *Abies grandis*, pre-chilling was clearly the best treatment, both in terms of numbers and of height growth. For *Abies nobilis*, pre-chilling and stratification were both successful in procuring good germination and tall seedlings.

Date of Sowing—Oak and Beech

At Kennington and Ampthill nurseries, experiments were carried out in which the yield and growth from autumn sowings of beech and oak, with and without an additional cover of three inches of soil during the winter, were compared with spring sowings. Results are given in Table 6 below.

Table 6

Numbers and Mean Heights of Seedlings of Oak and Beech—at End of First Season

Treatment	Ampthill Nursery				Kennington Nursery			
	Oak		Beech		Oak		Beech	
	No. per sq. yd.	Mean height (in.)	No. per sq. yd.	Mean height (in.)	No. per sq. yd.	Mean height (in.)	No. per sq. yd.	Mean height (in.)
Spring sown	241	2·87	259	4·39	261	6·87	282	9·09
Autumn sown—no additional soil cover	254	2·70	79	5·44	237	6·21	222	8·87
Autumn sown—with 3-in. additional soil cover during winter	149	2·68	93	5·84	261	6·87	279	8·57
Difference for significance: 5%..	21	0·21	39	0·67	32	0·42	46	0·40
1%..	29	0·29	53	0·90	44	0·59	65	0·56

For oak, in both nurseries, the yield from autumn sowings without extra cover was as good as or better than that from spring sowings. Given extra soil cover during the winter, at Ampthill, the yield dropped significantly, but at Kennington, it was equal to that of the best treatment. The height of oak seedlings from spring sowings was a little better than that from autumn sowings, but the difference was not important.

Beech seedlings at Kennington differed little in numbers and heights, whether spring-sown or autumn-sown, with or without cover. At Ampthill, spring sowings yielded about three times as many seedlings as autumn sowings. The reason for the poor yield from the autumn sowings is probably that there was very little severe frost during the winter 1956/57 and heavy soils such as that at Ampthill tended to remain caked rather than be shattered by the frost to form a fine crumb structure, thereby preventing plumule emergence. .

The result of this experiment is not so clearly in favour of autumn sowing as was the previous year's experiment (Faulkner and Aldhous, 1957—page 26). Nevertheless, the conclusion from the two experiments can be drawn that if storage of oak or beech seed during the winter is likely to prove difficult, there is a reasonable chance of getting as good results if the seed is sown in the autumn rather than in the spring.

At neither nursery was there any evidence of damage to seedbeds by pigeons or game birds, so that the value of the additional soil cover as a protection against this type of damage was not evaluated.

In the experiment at Ampthill, part was protected against mice using ⅜-inch mesh galvanised wire netting. Netting had no effect on yield or growth of either species.

Date of Sowing: Sitka spruce, Corsican pine and Tsuga heterophylla

The routine experiments on date of sowing, which are carried out as a check on the results of other experiments sown on different dates, were repeated at four nurseries (Kennington, Bramshill, Ampthill and Wareham). Seed of Sitka spruce, Corsican pine and *Tsuga heterophylla* was sown at fortnightly intervals from the first week of March to the middle of May. Table 6 below shows for each species the sowing date which yielded the greatest number of "usable" seedlings, i.e., seedlings $1\frac{1}{2}$ inches tall or over.

Table 6

Optimum Sowing Dates for Three Conifers at Four Nurseries, 1957

Nursery	Corsican pine	Sitka spruce	Tsuga heterophylla
Kennington	April 18th	April 5th	March 22nd
Bramshill	April 18th	April 5th	March 8th
Ampthill	May 2nd	March 22nd	March 22nd
Wareham	March 8th	March 8th	March 8th

Tsuga gave highest yields from middle or early March sowings, the yield from subsequent sowing falling off rapidly. Sitka spruce sown in mid-March or early April gave highest yields, the yield from later sowings falling steadily, but not so rapidly as for *Tsuga*. The best yield of Corsican pine was from sowings made in early April. However, for this species, the number of seedlings obtained was not greatly affected by date of sowing, though the tallest seedlings were obtained mostly from seed sown in April.

Seedbed Covering 232.323.5

In response to a suggestion by members of the Sub-committee on the Nutrition of Trees in Forest Nurseries, that Sitka spruce seed often germinates better under a thicker covering of grit than is currently recommended, experiments were carried out at Wareham and Ampthill nurseries comparing different thicknesses of seedbed covering. These ranged from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch for Sitka spruce and *Tsuga heterophylla*, and from $\frac{3}{16}$ inch to $\frac{3}{4}$ inch for *Abies nobilis*. The best yield of usable seedlings of *Abies* was obtained with $\frac{1}{4}$ inch cover at Wareham and $\frac{3}{4}$ inch at Ampthill; for Sitka spruce the best yield was obtained with $\frac{3}{16}$ inch cover at Wareham and $\frac{1}{4}$ inch at Ampthill, while for *Tsuga* the best yield was obtained with $\frac{1}{8}$ inch cover at Wareham and $\frac{1}{2}$ inch at Ampthill. While the agreement for each species is not very close, the optimum thickness of cover for Ampthill is consistently thicker than that for Wareham.

In previous years the best yields of Sitka spruce were obtained with the two thinnest coverings, while *Abies* did best with $\frac{1}{4}$ to $\frac{1}{2}$ inch of cover. The difference between nurseries was not so marked.

Irrigation 232.325.1

At Kennington nursery, an experiment was carried out in which the effect of two regimes of irrigation and an unirrigated treatment were compared. In both irrigation treatments, $\frac{1}{4}$ inch of water was applied when the soil moisture deficit exceeded $\frac{1}{4}$ inch in the period from sowing until mid-June; thereafter in one treatment, no further water was applied; in the other, ½ inch of water was applied whenever the soil moisture deficit exceeded ½ inch. During the first period, water was applied on 14 occasions. From mid-June until the end of the growing season (30th September) irrigation was applied on ten occasions.

Both irrigation treatments significantly increased the numbers and height of seedlings of Sitka spruce, *Tsuga heterophylla*, *Abies nobilis* and *Thuja plicata*, but had no effect on the yield of Corsican pine, Japanese larch, birch, beech or oak. There were no significant differences in the effect of the two irrigation treatments; this is probably because the weather turned wet for most of the time from mid-June onwards, after a very dry spring. These results are not quite as strongly in favour of irrigation as in the previous year, when seedlings of all species in the experiment responded to irrigation. Nevertheless the increases in yield were quite sufficient this year to justify irrigation on a large scale.

Undercutting Seedbeds 232.326.2

Undercut seedlings and transplants, and two-year-old untreated seedlings of Scots pine at Fleet, lodgepole pine at Inchnacardoch, and Sitka spruce at Newton were assessed for mean heights at the end of the growing season after treatment. Root collar diameter will be assessed later, at the time of lifting. Seedlings were raised at either 16 or 24 plants per square foot, either in drill or broadcast sown beds. Undercutting at a depth of three inches was carried out on all plots, and plots which were drill-sown also had their roots pruned laterally, between the drills. The months of cutting were August the first year, or March, April, May, June or July in the second year.

At Fleet the mean height data showed that undercutting Scots pine in August the first year, or March or April in the second year, caused a significant height reduction in comparison with the untreated plants. Seedling density had no significant effect on mean height, but drill-sown plants were significantly taller than those from broadcast plots.

At Inchnacardoch all the second year undercutting treatments on lodgepole pine caused a highly significant reduction in height growth, when comparisons are made with the non-undercut seedlings. Density of sowing and method of sowing had no significant effects on heights.

Date of undercutting had no significant effects on the mean heights of Sitka spruce at Newton. Seedlings raised at 24 per square foot and broadcast sown treatments both produced significant increases in seedling heights, when compared with seedlings raised at 16 per square foot and drill sowing respectively.

Experimental work on undercutting in the nurseries will be completed in 1958, but no firm conclusions on undercutting can be made until the experiments have been extended into the forest and assessed for survival and growth.

Maleic Hydrazide as a Growth Inhibitor

Work continued with experiments at Newton and Fleet designed to test the suitability of maleic hydrazide for checking the shoot growth of seedlings in "stand-over" seedbeds. Scots pine, Japanese larch, Douglas fir, Norway spruce and Sitka spruce were the species under test. The solutions of maleic hydrazide were applied in spring at the time when buds were swelling, except in the case of larch which was treated shortly after it had flushed. In previous experiments it had been shown that applications to larch before flushing were ineffective. The concentrations of the maleic hydrazide sprays were 0·145 per cent; 0·290 per cent; 0·435 per cent; and 0·580 per cent.

None of the species suffered significant casualties at either of the two nurseries, except for the Japanese larch at Newton where all the treatments caused a highly significant reduction in plant numbers. All species were susceptible to the effects of maleic hydrazide and all were checked in height growth. The amount of shoot elongation was approximately inversely proportional to the solution strength.

The plants from these experiments will be lined-out in 1958 to confirm the behaviour of similarly treated plants which were lined-out in 1955. These trials were reported on in the *Annual Report on Forest Research* for 1957 (page 32).

Seed Dressings: Miscellaneous 232.315.4

In many nurseries, pre-germination losses of conifer seeds are extremely high and may in extreme cases amount to more than 80 per cent. It is believed that soil fungi or seed-borne fungi, may be responsible for these losses, although in some cases nematodes and insects may be partly responsible. Red lead, which is the standard seed dressing for conifer seed, is ineffective against the agents causing the losses, and is used mainly to colour the seed to facilitate seed sowing.

In an attempt to determine the cause of pre-germination losses, Sitka spruce seed treated with Dieldrex 'A' or Dieldrex 'C' (proprietary combined dieldrin/organo-mercurial seed dressings for controlling seed-borne fungi and insects) was compared with seed treated with red lead. The experiment was conducted at Tulliallan. At the end of the growing season there were no significant height or total number differences between the three treatments. Since the yield of seedlings from all the treatments averaged only one-third of the potential, as indicated by germination tests, it is concluded that neither Dieldrex 'A' nor Dieldrex 'C' offer a solution to the problem. A more comprehensive range of materials is being tested in 1958.

Control of Insect Pests: Cutworm 232.327.4

At Kennington nursery, Oxford, an experiment was carried out testing the effect of two insecticides, Aldrin and Dieldrin at 100 cc. per 100 square yards (one gallon per acre) against larvae of noctuid moths (especially *Agrotis segetum*). Although attack by cutworm was not heavy, both materials gave good control, damage on untreated plots being of the order of 15 times greater than on treated plots. There was no appreciable difference in the effect of the two materials. There was, however, a suggestion that the application of water at the rate of one gallon per square yard at the time of application of the insecticide enhanced its effectiveness, but the increase was small and not sufficient to justify the cost of application of the additional water. Application of insecticide in mid-June, when larvae were hatching, was more effective in preventing damage than application later, when damage was first apparent but the differences were small. This experiment is the last in the present series. Full results of the series will be presented elsewhere.

Weed Control: Pre-sowing and Pre-emergence Weedkillers 232.325.24

At Bramshill nursery, an experiment was carried out comparing two persistent herbicides, monuron (N-(*p*-chlorophenyl)-N^1, N^1-dimethylurea) and C.I.P.C. (isopropyl-*m*-chlorocarbanilate), with the standard pre-emergence spray of vaporising oil at $1\frac{1}{4}$ gallons per 100 square yards (60 gallons per acre). C.I.P.C. was applied at rates from 5–20 grams per 100 square yards ($2\frac{1}{2}$–10 lb. per acre) and reduced both the total number of Sitka spruce seedlings at the end of the season and their mean height. Monuron applied at $\frac{1}{2}$–2 lb. per acre affected neither height nor numbers, treated plots taking no longer to weed than those treated with vaporising oil. However, experience with monuron in relation to other crops suggests that its phytotoxicity varies according to the weather, and the result of this experiment will have to be thoroughly confirmed before monuron can be considered as a safe alternative to vaporising oil.

Experiments to evaluate C.D.A.A. (alpha-chloro-N, N-diallyl acetamide) and C.D.E.C. (2-chloroallyl-NN-diethyl-dithio carbamate) as pre-emergence weed-killers for conifer seedbeds were carried out in three nurseries, Kennington, Bramshill, and Ampthill. Materials were applied at rates equivalent to 40, 60 and 80 gm. per 100 square yards (4, 6 and 8 lb. per acre). There were three dates of application 16, 9 or 2 days before sowing, and materials were either cultivated into the top two to three inches of the ground or left on the surface. Four species were sown, Sitka spruce, Corsican pine, Japanese larch and *Tsuga heterophylla.* At all nurseries Japanese larch seedlings were damaged by C.D.A.A. at 6 and 8 lb. per acre and by C.D.E.C. at 8 lb. per acre. Sitka spruce and *Tsuga* were little affected, and Corsican pine was intermediate in response. C.D.A.A. was the more potent weedkiller, but when applied at the highest rate and cultivated into the ground, reduced seedling yields of all species.

C.D.E.C. had less effect on the crop but was not as good a weed-killer as vaporising oil. It also was more phytotoxic when cultivated into the ground.

At Bramshill nursery, the effect on weed growth and seedling yield of allyl alcohol, applied as a drench or injected into the ground ten days before sowing, was examined. Allyl alcohol was applied at $\frac{1}{3}$, $\frac{1}{2}$ and $\frac{2}{3}$ gallon per 100 square yards (16, 24 and 32 gallons per acre). In the drench treatment, water at the rate of one gallon per square yard was mixed with the allyl alcohol, and the mixture applied by watering can. The injection treatment was applied by means of the Auchincruive injector, with eight tines set five inches apart and two to three inches deep in the soil. Four species were sown in the experiment, namely Japanese larch, Sitka spruce, Corsican pine and *Tsuga heterophylla.* None was affected by any allyl alcohol treatment. The time taken to remove resistant weeds by hand was slightly greater on drench treated plots compared with the control plots (which were given the standard pre-emergence spray of vaporising oil); the weeding time on plots receiving injected allyl alcohol was very significantly greater than on drench-treated and control plots. The rate of application of allyl alcohol, when applied as a drench, had no effect on the weeding time, but when it was injected, the plots receiving $\frac{1}{3}$ gallon per 100 square yards took significantly longer to weed than plots receiving either of the higher rates.

This result confirms that obtained from a similar experiment in 1956 (Faulkner and Aldhous, 1957). Allyl alcohol applied as a drench at $\frac{1}{3}$–$\frac{2}{5}$ gallons of allyl alcohol per 100 square yards (16–20 gallons per acre) with one gallon of water for every square yard, gives as good a control of weeds as pre-emergence sprays with mineral oils. At present, however, the cost of this allyl alcohol treatment is very substantially more than the mineral oil spray, and it is unlikely to supplant it.

Pre- and Post-emergence Weedkillers

Dalapon (2, 2-dichloroproprionic acid) was tested as a pre- and post-emergence weedkiller on Sitka spruce seedbeds in experiments at Kennington nursery, Oxford, and at Bramshill nursery, Hants. Dalapon formulated as the sodium salt was applied at the rate of 30, 45 and 60 grams of active ingredient per 100 square yards (3, 4½ and 6 lb. per acre). At both nurseries, all treatments significantly reduced numbers and heights of seedlings, especially in the post-emergence treatments where there was almost complete loss of crop.

At Bramshill nursery, a new weedkiller WL 1705, developed by Shell Chemicals, was tested as a pre- and post-emergence weedkiller. WL 1705 was applied at 20, 35 and 50 grams per 100 square yards (2, 3½ and 5 lb. per acre) as a pre-emergence spray alone, and as a pre- and post-emergence spray, the post-emergence treatment being first applied three and nine weeks after the pre-emergence spray. The control treatment was given a vaporising oil pre-emergence spray at 1¼ gallons per 100 square yards (60 gallons per acre) and post-emergence sprays of white spirit at ½ gallon per 100 square yards (25 gallons per acre), commencing nine weeks after the pre-emergence spray. The pre-emergence spray of WL 1705 had no effect on seedling growth or germination, but sprayed plots took very significantly longer to hand-weed compared with plots sprayed with vaporising oil. All three rates of post-emergence spray with WL 1705, commencing three weeks after the pre-emergence spray, seriously reduced seedling numbers and height without any significant reduction in weeding time. Of the *post-emergence* spray applications commencing nine weeks after the *pre-emergence*, that at 50 grams per 100 square yards significantly reduced both the numbers and height of seedlings; the heights of seedlings treated at the two lighter rates were appreciably (but not significantly) smaller than control seedlings. However, the time required to hand-weed these plots was significantly greater than that for the control plots.

At Bramshill nursery the effect on weeds in Sitka spruce seedbeds of two new blends of Shell weedkiller 'W' was compared with that of the blend currently marketed, and with 'Esso 100' white spirit. All four oils were applied at $\frac{5}{16}$, ½ and $\frac{11}{16}$ gallons per 100 square yards (15, 25 and 35 gallons per acre), commencing seven weeks after germination. No significant differences in seedling numbers, height or in the time required to hand-weed resistant weeds were found.

At Bramshill nursery, and Kennington nursery, 'Royal Standard' paraffin was evaluated as a post-emergence weedkiller. 'Royal Standard' is commonly used for lighting; it has an aromatic hydrocarbon content comparable to that of the white spirits currently used to control weeds in forest nurseries, but costs only one-third as much. It was applied at $\frac{5}{16}$, ½ and $\frac{11}{16}$ gallons per 100 square yards (15, 25 and 35 gallons per acre) at intervals of three weeks, commencing four weeks after germination was complete on all plots. At both nurseries 'Royal Standard' at all rates of application tested had no effect on the seedling crop but also had little effect on the weeds, the weeding time with one exception being significantly greater than the time required to weed the control plots sprayed with white spirit.

Similar experiments were carried out at five Scottish nurseries, in which either Shell 'W' or 'Esso 100' oils were applied as post-emergence sprays at recommended rates to Scots pine, lodgepole pine, Japanese larch, Douglas fir, Norway spruce and Sitka spruce. These treatments were compared with 'Royal Standard' paraffin, Shell 'W/57', and Shell 'W/8' at 2½, 3¼ or 4 pints (approximately) per 100 square yards (15, 20 or 25 gallons per acre) applied to all species. Shell 'W/57' and Shell 'W/8' are both experimental oil products which have been suggested as being safe and suitable substitute weedkillers for use on conifer seedbeds.

These experiments confirmed that 'Royal Standard' paraffin has no value as a weedkiller in conifer seedbeds. The experimental oils, Shell 'W/57' and 'W/8', when applied rate for rate, compared very favourably with commercial Shell 'W' or 'Esso 100', both in regard to the amount of weed control and the degree of phytotoxicity to seedlings.

A demonstration of the effect of the current recommendations for the post-emergence use of mineral oils on seedbeds and lines was carried out at nurseries at Kennington, Bramshill, and Wareham, and also at Savernake and Roudham. Altogether, seedbeds containing 11 species were included at one or other nursery. Oils were applied at the recommended rate of 2½ or 4 pints per 100 square yards (15 or 25 gallons per acre) according to species, and at one and a half times the recommended rate. No significant reduction in numbers or mean height of seedlings was found on plots sprayed with oils at the standard rate; in several instances, however, the height of seedlings was reduced on plots sprayed at the higher rate. On all beds, weeding times were appreciably reduced on plots receiving the oil spray, the reduction being greater on plots sprayed at the higher rate.

Transplants of nine species were also included in the demonstration. White spirit or vaporising oil was applied at 4 and 6½ pints per 100 square yards (25 and 40 gallons per acre). Good control of weeds was obtained in both cases. In no instance was there any reduction in transplant height or survival where plants had been sprayed at the lower rate; the mean height of European larch, Lawson cypress and Douglas fir transplants was significantly less on plots sprayed with vaporising oil at the higher rate, than on control plots, while the mean height of Norway spruce transplants was less on plots sprayed with white spirit at the higher rate. The reduction in height was often accompanied by browning of the lower foliage but this browning was seldom thought sufficient reason not to plant affected transplants.

Weed Control in Fallow Land

The experiment commenced in 1953 to determine the effect of various non-selective weedkillers on weed growth and conifer crops in the years following treatment, was continued. Plots which had been treated with monuron (chloro-dimethylurea) at 200 and 400 grams per 100 square yards (20 and 40 lb. per acre) were lined out with Sitka spruce, Scots pine, Japanese larch and Douglas fir. Plots treated with monuron at the lower rate carried crops similar in height and survival to the control plots; on plots treated at the high rate, the needles of Scots pine transplants browned at the tips, and height growth was significantly less than on control plots, while Sitka spruce transplants developed yellow tips on the ends of their needles. Douglas fir and Japanese larch transplants were unaffected on these plots. Weed growth was very significantly less on the plots treated with monuron at the heavy rate.

Frequency of Weeding

At Bramshill nursery, an experiment was carried out to determine the effect of frequency of weeding on total weeding time, and on the growth of weeds. Seedbeds of Sitka spruce were weeded at intervals of two, four and six weeks following a pre-emergence spray of vaporising oil at 1¼ gallons per 100 square yards (60 gallons per acre). Table 7 below shows the results of the experiment.

Table 7

Effect of Frequency of Weeding on the Numbers and Height Growth of Sitka Spruce Seedlings and upon Total Weeding Times

Frequency of weeding	No. of seedlings per sq. yd.	Mean height inches	Total weeding time mins. per sq. yd.
Intervals of 2 weeks	568	2·54	15·4
Intervals of 4 weeks	543	2·58	14·6
Intervals of 6 weeks	583	2·48	25·7
Differences for significance: 5%	69	0·18	10·3
1%	96	0·24	13·64

It will be seen that, in this particular season, frequency of weeding had no significant effect on the number of seedlings or their height growth, but that the total weeding time when weeding at the longest intervals was nearly twice as great as when weeding more frequently. The larger part of the difference arose in the latter part of the growing season; during May and June, when the weather was dry, weed growth was light on all plots and differences were small.

Plant Handling and Storage 232.412.4

In order to determine how long seedlings could be exposed out of the ground without protection, before their ability to survive became impaired, experiments were carried out at Kennington Nursery. Seedlings of Corsican pine, Douglas fir and Lawson cypress were exposed on two occasions, the first in early April when the weather was damp and fairly still and the relative humidity did not drop below 87 per cent all day, and the second in late April on a dry, dull though no warmer day, with a fairly strong wind, when the humidity was 77 per cent early in the morning falling to 54 per cent by noon. After varying periods of exposure up to six hours maximum, the plants were lined out. Survival was assessed at the end of the growing season. Plants which had been exposed on the first date for varying periods up to six hours showed no differences in survival from the controls which had not been exposed, but in those plants which had been exposed under drier conditions on the second occasion losses began to increase significantly for exposure periods of more than two hours, while, after six hours' exposure, nearly all plants died. Measurements showed that the loss in weight that occurred in six hours on the first occasion occurred in two hours in the second.

Storage in Boxes. In the long-term nursery nutrition experiments, small numbers of plants from several dozen different treatments have to be kept separate. Storage in boxes was considered a possible alternative to the present practice of lifting the plants and heeling them in. To test the feasibility of this, an experiment was carried out at Kennington, comparing three densities of storage of seedlings in wooden boxes 18 × 12 × 6 inches. Seedlings were packed 250, 350 or 500 to a box, gaps between rows of plants being filled with moist 'Sorbex' peat. The boxes were stored under shelter from November till mid-March and the seedlings were watered twice towards the end of the storage period. There were no significant differences in the survival or growth of seedlings from the various treatments after a season in the transplant lines.

Storage in Polythene Bags. At the nurseries at Kennington, Wareham, Bramshill and Alice Holt, experiments were carried out to determine how long plants could safely be stored in polythene bags (see Faulkner and Aldhous, 1957). In these experiments plants were lifted at intervals from mid-November to mid-March, and immediately put into polythene bags, each bag containing either 100 seedlings or 50 transplants. The bags were closed and secured with string so that they were virtually airtight, and they were stored upright on racks in sheds away from direct sunlight but exposed to free circulation of air. Thirteen species were included in the experiments.

At intervals from the end of November until mid-May, sets of plants were removed from the bags and lined out so that there were comparisons of lining out at different dates after varied periods of storage.

Results by groups of species for this series of experiments can be summarised as follows:

Pines. Scots pine stored in polythene for periods up to four to six months, with only small decreases in survival at the end of the longest periods. Lodgepole pine also survived well, and when lifted in the winter stored in bags for up to four months without harm. Plants lined out late in the season, whether stored for very long or moderate periods, did not survive well, but this appeared to be due to late planting rather than storage. Corsican pine did not do as well; the survival of seedlings stored for longer than two months decreased, the longer the period of storage. Corsican pine transplants were more tolerant and stored well up to four months.

Spruces. Both Sitka spruce and Norway spruce survived storage in polythene bags outstandingly well. Survival of plants stored for six months in polythene was as good as that of plants lined out immediately after lifting.

Larches. Survival of European larch and Japanese larch was good for all periods of storage up to four months, so long as plants were lined out by the middle or the end of March. Plants remaining in polythene after this date came into leaf regardless of the time they had been in bags, and the new foliage was creamy white in colour and very soft. On lining out these plants, all new foliage died back and only a few of the strongest or biggest plants were able to produce a new growth of leaves. Very few seedlings, and only a proportion of the transplants lined out in April, survived and were fit for planting.

Douglas fir. Survival of plants packed with dry foliage and stored up to four months was good. For longer periods, the survival was reduced, though this may have been partly due to late lining out.

Lawson cypress, Thuja plicata and Tsuga heterophylla. Results for these three species were not consistent from one nursery to another. All tolerated winter storage up to four months in at least one nursery, but there was evidence that they were more sensitive to conditions at the time of lifting than other species. In the spring, all three species tolerated storage in polythene for six weeks in at least one nursery, though they were intolerant of late planting.

Abies nobilis was included in experiments at one nursery and was outstandingly bad. The species seemed unable to tolerate storage in polythene for any period longer than a fortnight.

General conclusions that can be drawn from the experiments were:

(i) Transplants are better able to tolerate storage in polythene bags than seedlings.

(ii) Plants store better when lifted in a dormant state than when bud or root development has begun.
(iii) Plants lifted with wet foliage do not store as well as plants lifted with dry foliage.
(iv) Spread of fungi is not a great hazard—*Botrytis* in particular does not spread in the bags.

Storage in Polythene—Density of Stacking of the Bags

At Kennington and Alice Holt nurseries, experiments were carried out to determine the effect of density of stacking of bags on the ability of plants to survive storage in polythene. By arranging 25 bags in as compact a 5 × 5 square as possible, a wide range of conditions was obtained from bags completely surrounded to bags free on three out of four sides. No differences were found between plants from bags in any position. (See Faulkner and Aldhous, 1957, pages 30 and 34–36.)

Comparison of Different Methods of Handling Plants

In Scotland a small experiment was carried out comparing three methods of handling plants between the time they are lifted in the nursery and planted in the forest. As losses of Douglas fir following planting are normally higher than with most other conifer species, and as it is frequently suggested that this is partly due to faulty handling and packaging methods, Douglas fir was used as the test species.

At Kirroughtree nursery, Kirkcudbrightshire, consignments of two-plus-two and one-plus-two Douglas fir transplants were packed in the nursery and transported to the forest in one of three ways.

(*a*) in polythene bags, or
(*b*) in large open-ended bundles prepared by placing smaller bundles of plants with their roots together and surrounded with damp moss, the whole being surrounded by hessian, leaving the plant tops exposed at each end;
(*c*) lifted and bundled and transported in the normal manner without outside wrappings.

On arrival at the forest, the plants were kept for approximately two weeks in the polythene bags or hessian protected bundles, and the unprotected plants were sheughed (heeled-in) in the normal manner. Plants from the three treatments were planted in replicated blocks and at the end of the growing season were assessed for survival.

The forest planting trials were conducted at Brownmoor, Yair Hill and Elibank Forests. At Brownmoor, normal sheughing resulted in a highly significant increase in the death rate when compared with results from plants in hessian-protected bundles or polythene bags. There were no significant differences in the survival rate between the polythene and hessian bundle method of transport and storage at Brownmoor. At Yair Hill and Elibank, there were negligible differences in survival rate between the three treatments.This experiment has shown therefore, that in certain instances the transport of plants in polythene bags or open-ended hessian bundles can lead to a higher survival of the plants in the forest, as compared with the normal method, without wrappings.

REFERENCE

FAULKNER, R. and ALDHOUS, J. R. 1957. *Report on Forest Research*, Forestry Commission, London. Pages 19–36.

SILVICULTURAL INVESTIGATIONS IN THE FOREST

(A) SOUTH AND CENTRAL ENGLAND AND WALES

By R. F. WOOD and G. D. HOLMES

Afforestation Problems

Ground Preparation and Planting Methods 232.42

There is little fresh to report under this head. Forest experiments in the last three years have been directed mainly at assessment of the value of intensive cultivation, including deep sub-soiling and complete ploughing, in terms of subsequent crop increment. In practice, cultivations in preparation for planting have been the minimum necessary for drainage or temporary vegetation suppression. On many compacted or impeded mineral soils it may be that more intensive soil disturbance may be justified by beneficial effects on crop root development and increment in later years. This remains to be proved by experiments such as those at present under way at several forests including Wareham, Haldon, Taliesin, Croft Pascoe and Wilsey Down, testing the long-term effects of varying degrees of cultivation.

Afforestation Problems on Particular Types of Land 233

Southern and Western Heaths: Croft Pascoe Forest, Cornwall

It is now nearly five years since work started at the small experimental forest at Croft Pascoe, on the Lizard. During this time 23 experiments have been laid down, concerned mainly with choice of species and afforestation techniques for the more difficult types of south-western heaths. The Lizard site is impoverished and exposed, and is of special interest as it is located on serpentine rock, a formation on which there has been little afforestation experience. Early results of these experiments were described at some length in *Rep. For. Res.* 1957 and developments during 1957 generally strengthen the conclusions made at that time. Crop establishment has not been as difficult as anticipated, providing the site is ploughed before planting, and all trees receive a dressing of phosphate. Most species have established themselves satisfactorily on normal single-furrow ploughing, but growth on deep complete ploughing is markedly better. The growth response to phosphate fertiliser is most striking, and manured trees of Sitka spruce and *Pinus radiata* are up to 500 per cent larger than untreated controls, after four seasons growth. A recent experiment on rates of phosphate indicates that important increases in growth rate can be obtained by raising the application rate above the commonly accepted two oz. superphosphate-per-tree level. A total of 24 species are on trial in this area, and of these the most promising are Sitka spruce, *Pinus radiata* and coastal lodgepole pine. *P. radiata* is outstandingly the most vigorous species, and there now seems little doubt that this will be the first choice for large-scale afforestation under these conditions.

Wareham and Purbeck Forests

In the last two years an effort has been made to extend a selection of the best species from the existing old species trials at Wareham on to modern methods of ground preparation (including single-furrow tine ploughing, and intensive complete cultivation followed by ridging for drainage). These new experiments are now established and should permit a fresh appraisal of species, using a degree of cultivation which was impossible at the time when the early species trials were planted. Species under trial include *Tsuga heterophylla*, Corsican pine, Japanese larch, Lawson cypress, lodgepole pine, *Pinus radiata*, *P. peuce*, *Thuja plicata*, and red oak. *Hylobius* weevils and also heather weevils damaged many species during 1957, and it was necessary to spray all plants with DDT emulsion to prevent excessive injury. Most species are now growing well, with the exception of *Cupressus macrocarpa* which succumbed to severe early frosts in the year of planting. This species has now been replaced by X *Cupressocyparis leylandii*.

Hill Land in Mid-Wales: Coed Taliesin, Cardiganshire

This forest has now become a major centre of experiments on afforestation methods on mineral soils over shale in the west. The site is similar to a large area in mid and south Wales characterised by compacted, deep and freely drained loamy soils, usually on steep exposed slopes.

No forest establishment experimental work has been done on this type in the past, but the main factors limiting tree growth are thought to be exposure, and competition of the dense vegetation cover of dwarf gorse, heather and grass which develops when grazing ceases. A large programme of experiments was started in 1956 and 1957, and 14 experiments have been planted, including species trials and studies of cultivation, manuring and vegetation control methods.

Preparatory cultivation methods are being examined in two main experiments testing single and double mould-board single-furrow ploughing, and complete ploughing, all methods with and without deep subsoiling. A species trial of the best indicated species, namely *Abies nobilis*, Sitka spruce, and *Tsuga heterophylla*, planted pure and also in mixture with a matrix of coastal lodgepole pine, has been superimposed on these ploughing trials.

Much of this type of land is too steep for ploughing, and a large number of species are under test, planted on hinged turfs on steep slopes, and on ploughed land on less severe slopes. In addition to the species mentioned above, these include Japanese larch, Lawson cypress, *Thuja plicata*, *Cryptomeria japonica*, *Picea engelmannii*, *Pinus peuce* and *Abies amabilis*. Subsidiary species trials include *Abies alba*, *A. lasiocarpa* and X *Cupressocyparis leylandii*. All species survived well during the first season, except on complete ploughing, where initial losses were higher, probably due to concealed cavities and root drying. Otherwise there is little to choose between plough methods at present.

Abies nobilis, Sitka spruce, lodgepole pine and X *C. leylandii* are the outstanding species so far, and all exhibit striking growth responses to phosphate applied at planting.

Survey of Established Woods on Exposed and Elevated Sites

For some years the Research Branch has been laying down trial plantations on land which normally would be classified as unplantable, due to exposure or poor soil conditions, and useful information is being obtained from these trials.

However, it will be many years before such trials yield conclusive results. In the meantime it is likely that much can be learned by observations of the numerous existing older woods growing on limiting sites on private and Forestry Commission land throughout the country. Preliminary steps have been taken to initiate a survey of these woods in order to build up a body of information on the growth of species, particularly on exposed sites.

Growth of Long-Term Mixtures 235.5

The long-term experiments laid down in seven forests in 1955 and 1957, with pure and mixed crops of Douglas fir/*Tsuga*, and Sitka spruce/*Tsuga*, have been described in previous reports. No further plantings were possible during the year, but the series will be extended to include other species in the next few years. Meanwhile, the development of the existing mixtures is being studied.

Forest Stand Improvement

Manuring at the Time of Planting 232.425

Field work has been confined mainly to examination of phosphate responses in connection with afforestation of special sites, some of which are mentioned above. Trials were also continued at several centres to check on the validity of subsoil P_2O_5 analyses as a means of forecasting crop responses (see *Ann. Rep. For. Res.* 1956, page 132). These tests also include examination of forms and rates of phosphate on a variety of poor sites.

Almost without exception, past trials of fertilisers at planting have involved dressings placed close to each plant, and there have been no trials of overall fertiliser application at this stage. Broadcast dressings are of course of great interest on established crops, but with the efficiency of modern methods of spreading, using aerial or ground equipment, it seems pertinent to examine the effectiveness of broadcasting on new plantings. Small-scale trials have been laid down recently to test effects both on crop and vegetation development.

Improvement of Checked Plantations 237.4

Work was continued at several centres, notably Wilsey Down, Haldon, Wareham, Tarenig and Ringwood, to examine methods of improving the growth of checked or unsatisfactory spruce and pine crops on infertile sites dominated by heather and gorse vegetation. Fortunately the area of such crops is not great, and most are associated with plantings made before the advent of modern methods of mechanical ploughing. Nevertheless, they present quite a serious problem in some localities. A considerable programme of experimental work has been undertaken in the last two years on these areas, as it is felt that elucidation of such problems will yield valuable knowledge which can be applied to growth and nutritional problems of crops under a variety of conditions.

At Wilsey Down, Cornwall, checked crops of Sitka spruce planted in 1934 continued to grow vigorously during the third year following broadcast phosphate dressings applied in 1954. Trees receiving 6 cwt. potassic superphosphate per acre are now five to six feet high, compared with unmanured trees which are still in a state of growth check at 1½ to 2 feet. Factorial tests of P. and K. fertilisers indicate that these effects are associated almost entirely with the phosphate component of the dressings. This has now been followed in 1957 by large-scale mechanical broadcasting, using a tractor-mounted 'spinner' type spreader for application of granular triple superphosphate at rates up to 6 cwt. per acre, to examine the responses to different doses of phosphate and the costs of practical scale treatments.

The effectiveness of broadcast dressings applied to crops struggling in dense vegetation of heather, *Molinia*, gorse, etc., has been something of a surprise, and further experiments have been established to assess the value of placed applications compared with broadcast dressings at the same total rates. Checked and slow-growing spruce trees at Wilsey exhibit a most unusual summer wilt or droop of young growth of lateral and leading shoots. This symptom disappears on trees receiving phosphate, but may reappear within two years on trees receiving applications as low as two cwt. superphosphate per acre. The symptom is suggestive of trace element deficiency troubles in several crop species, and trials were started during 1958 to examine effects of foliar sprays of several elements, including copper, zinc, boron and molybdenum.

Similar trials of broadcast fertilisers on slow-growing Scots pine and Corsican pine crops on infertile Eocene heath sites at Wareham are also showing marked growth responses, both to phosphate and nitrogen additions. The first effects are marked improvement of foliage colour, more than 50 per cent increase in needle length, and better retention of older needles. All these add up to a striking improvement in the general appearance of vigour in the tree crowns. Substantial shoot growth improvements are now apparent following dressings applied in summer 1956. All these crops are growing in a dense cover of heather, but chemical removal of the heather by overall spraying with 2,4-D has had relatively little effect on crop growth in the first season following treatment. However, effects on crop growth are now appearing and the effect of added phosphate was markedly superior on plots freed of heather competition.

The same pattern of results is appearing in similar experiments on pine crops on the tertiary sand and gravel formations at Haldon forest. These observations indicate that manuring and vegetation control treatments in checked or slow-growing crops can produce marked improvements in a short time. Of course these effects may be quite temporary, and only continued observations in experiments of this type can determine the long-term effects and economic value of such ameliorative treatments. More extensive trials of rates of phosphate, and several forms of nitrogen fertiliser, are required in order to obtain long-term crop data.

Current investigations on checked areas at Haldon, Wilsey and Wareham also include examination of methods of total or partial replacement of the existing crop, involving trials of mechanical clearance, cultivation methods and tests of species.

Nutrition of Pole Stage Crops 237.4

The possibilities of increasing the increment of established conifer crops by improving nutrition in the early pole stage of development has excited a great deal of discussion in recent years, mainly as a result of work on the Continent and in the U.S.A. Very little is known in Britain about the nutrition of forest crops at this stage of growth, and experiments are required to assess the scale and economic significance of growth responses which can be obtained by fertiliser additions.

Following an extensive survey of the literature, trials were started in 1957 with the object of assessing the long-term effects of nutrient additions over a range of sites. The first trials were restricted to low-quality Scots pine crops on infertile sites at Bramshill, Wareham and Haldon. Currently, the work is being extended to include spruce as a more demanding species. The trials established so far are somewhat complex factorial tests of rates of nitrogen, phosphorus, potassium, calcium, magnesium and fritted trace elements, on small plots, to examine the nature and persistence of growth responses to single and compound dressings. Effects are being assessed in terms of nutrient uptake by the crop, related to the girth and height increment of sample trees. Extensive soil and foliar nutrient analyses are being included in the assessments, as these may provide a means of diagnosing probable nutrient deficiencies under various conditions. Attention is also being paid to formulation of fertilisers, particularly nitrogen and potassium, in order to secure maximum retention of these materials on the site.

Experiments in 1957 on forms of nitrogen fertilisers for application to established crops indicated that salts of weak acids appear to be more efficiently absorbed by organic matter than salts of strong acids, such as nitrates or sulphates (see W. G. Hinson and E. R. C. Reynolds 'Cation Adsorption and Forest Fertilisation, *Chemistry and Industry* 1958, pages 194–196).

A vernier-reading metal girth-band, fixed to the stems of trees, has been adapted for use in these experiments to provide precision readings of girth increment patterns during each growing season on sample trees. (Franklin, G., Liming, *Jour. For.* 55(8) 1957, pages 574–577.) Such intensive assessments are likely to provide a better picture of the time and nature of responses than the usual less precise and infrequent girth measures.

The most marked responses are to be expected on the really impoverished sites, where, for obvious reasons, only low-demanding pine species have usually been planted. It may be that better nutrition could enable more demanding and higher yielding species to be grown, and this point is to be examined by fertiliser trials in selected Research Branch Species Trial plots on poorer sites.

Derelict Woodland Investigations 25

Active experimentation in this project has now ceased, at least for the time being. A number of experiments comparing different silvicultural methods of converting coppice and scrub will continue to yield valuable information for at least 20 years. Certain experiments comparing various mechanical methods of clearance may continue to be of interest during the establishment phase, since it is hoped that some information will be gained on the effects of different machines on the soils, and hence on the crops.

A full account of the investigations in this project is now in an advanced state of preparation.

During the year, the V-Blade Scrub Cutter (described in *Rep. For. Res.*, 1957, by A. D. Miller) completed several trials in various types of growth. Generally speaking, the tool confirmed its early promise, and has shown itself to be a very flexible instrument capable (under suitable conditions) of site preparation for planting by complete clearance, or where cover is silviculturally desirable, by the clearance of strips through the coppice or scrub. The costs of the various trials have been carefully analysed, and will be fully discussed in the report now under preparation.

There appears, however, to be little doubt that where mechanical clearance is silviculturally admissible, and where the areas concerned are large enough to absorb the high costs of transport of the (necessarily) powerful tractors, some such device as the V-Blade will usually show considerable economies over hand site preparation.

Chemical Weed Control

Non-Selective Control of Vegetation in Fire Traces 441.432.18

Intensive trials of complete herbicides for control of mixed vegetation in fire traces, started in 1956, were continued throughout 1957. First results were described in some detail in the 1957 report, and the series will shortly be written up in full for publication. Information has been obtained on the susceptibility of a large number of common weed species to various weed-killers. The next stage is to test selected treatments on a more extensive scale for assessment of efficacy and cost, in comparison with normal mechanical methods of suppressing inflammable vegetation. With the exception of borax compounds, the majority of 'complete' herbicides, notably monuron, sodium chlorate and arsenicals, have proved disappointing for control of well established swards. Very high rates are necessary for an efficient initial kill, but considerably lower rates suffice to maintain weed-free conditions. Judging from results to date it is much more efficient to secure an initial kill of established mixed herbage using selective herbicides, such as 2,4-D/2,4,5-T mixtures, and TCA or dalapon, following up these with maintenance treatments of non-selectives (borax, monuron, etc.), at relatively low rates. The eventual annual cost of fire trace maintenance with such a regime of herbicide treatment remains to be investigated, but on present evidence it would seem to be competitive with repeated mechanical cultivation and likely to be much cheaper than manual screefing, as is sometimes practised on steep or difficult sites.

Control of Grass 441.236.1

Arising out of the work on fire traces, interest has been aroused in the practical possibilities of using selective herbicides for controlling established grass swards in preparation for planting, and also during the early stages of crop establishment. Development of a thick grass mat is common in cleared woodland areas, on chalk downland and in derelict grazing land in the west and south-west. Such vegetation competes effectively with newly planted trees. In many cases it is possible to secure temporary grass suppression by ploughing before planting, but there are many areas where this is impossible, and hand screefing or repeated cutting are the only measures possible.

Experiments established in 1958 include test applications to unplanted ground occupied by various swards ranging from downland grass to dense *Molinia*. Parallel with these are trials on planted land, including checked oak, Norway spruce, ash and sycamore in dense grass, and newly planted poplar on a grassy site. The main compounds tested are dalapon and amino-triazol, with supplementary tests of simazin and monuron. At some sites these treatments are being compared with mulching and hand-screefing methods of control.

Control of Woody Growth 441.414.12

Recommendations on chemical control methods for the majority of woody species were issued during 1957, with the object of encouraging large-scale trials under practical conditions. A great deal is now known of the susceptibilities of the important species to 2,4-D and 2,4,5-T; and a large part of current work is devoted to examination of equipment and methods, and accurate assessment of costs and results of large-scale applications. The trials during 1958 are being carried out in collaboration with Conservancies; they include large-scale spraying of cut stumps, overall foliar spraying and basal bark spraying of unwanted standing growth in preparation for planting. In addition, a large-scale experiment has been started comparing the costs and long-term effects on crop development of several methods of machine weeding and chemical control of mixed weed growth in young plantations.

Experiments on methods of controlling standing growth were continued on a variety of species. Basal bark spraying with 2,4,5-T, in oil, has generally proved effective; but hawthorn and rhododendron have proved resistant. This technique is costly in labour and materials, and invert emulsions applied in water are currently under test to examine the possibilities of replacing the costly oil diluent by water for basal bark and stump treatments. Application of soil treatments such as 2,4,5-T injection, or monuron soil additions, for killing standing growth, have so far proved disappointing.

Recent tests of methods of cut-stump treatment for prevention of coppicing indicate the importance of treating the bark of the stump rather than merely the cut surface, if epicormic initials are to be killed.

On individual species, willow stumps have proved surprisingly difficult to kill with 2,4,5-T, and ammonium sulphamate was the only compound to give full control of this species. This is also the case with rhododendron stumps. Blackthorn stumps on the other hand proved easy to kill, but root suckering may occur some distance from the stump, requiring a 2,4,5-T foliar spray for control. Oak has not proved an easy subject for stump treatment with 2,4,5-T, and trials are being extended to test the effectiveness of other compounds.

Control of low growth by overall foliar spraying from the ground may be of value in some instances, and work during 1957 was concentrated on development of methods of controlling dwarf gorses, *Ulex gallii* and *U. europaea*, which can be serious plantation weeds in parts of Wales and elsewhere. Results of 1957 trials at Taliesin and other centres showed that *U. gallii* could be effectively controlled by summer spraying with 2,4,5-T at 3–5 lb. (acid) per acre, and applications were later extended to cover 20 acres of land in preparation for planting at this forest. Similar results were obtained at Tarenig, Cardiganshire, for controlling gorse selectively in a checked plantation of Norway and Sitka spruces. Such treatments completely transform the ecology in sprayed areas, and the long-term effects of this in terms of crop development remain to be assessed.

Calluna control trials in checked or slow growing crops at forests, including Wareham and Haldon, present a similar case. Here summer spraying of 2,4-D has proved highly effective, and the result of selective clearance of *Calluna* as the dominant part of the vegetation cover are beginning to show by enhanced crop growth two years after spraying. The effects of added fertilisers are also much greater on sprayed plots. The effects of *Calluna* control prior to planting requires investigation, as it seems possible that such a site transformation may improve growth rates and widen the choice of species in a given area.

Protection of Seeds and Trees Against Damage by Animals

Protection of Direct Sown Seeds 232.336

The trials of seed dressings of animal-repellent compounds described in the last report were continued. Also, the effectiveness of cold bitumen emulsion sprays applied to the soil surface after sowing, in reducing seed losses due to mice, were confirmed. This technique is very simple, and has the advantage that it also acts as a moisture-retaining mulch, hastening seed germination. The method is being subjected to large-scale tests at several centres during 1958. However, it is considerably more costly than protection by seed dressings, and further work is required on the latter.

Protection of Planted Trees 451.2:414.14

An extensive experiment on the use of endrin and toxaphene as toxins for controlling field voles (*Microtus agrestis*) was completed at Crychan Forest during the year. Results are reported in detail on page 148. The use of animal repellents for protection of young trees against damage by voles and deer has been a subject of interest for some time. Trials during 1957 included applications for protection of Douglas fir, *Thuja plicata* and Japanese larch against voles at Slebech and Radnor Forests. Similar trials of tree protectants against deer damage were made at Brightling, Quantock, Rogate and New Forest, on poplar, beech and red oak. Results are awaiting final analysis, but tentative conclusions indicate that chemicals can be useful for protection of *stems* against damage by gnawing or rubbing. Protection of foliage and young shoots has proved much more difficult owing to the phytotoxic effects of some of the more efficient repellents, or because treated shoots rapidly grow out of the protective cover. Stem treatments with bone oil and some proprietary repellents, notably 'Arikal' and 'Wiltex', provide useful protection for several months after application.

Miscellaneous

Preliminary Trials of Gibberellic Acid for Stimulation of Growth of Seedlings and Transplants 160.27

Preliminary tests of this growth regulator were completed on a wide variety of species. Results showed that many species failed to respond appreciably, with the notable exception of beech, which showed considerable growth increases following lanoline smear or injection treatments to the leading shoot. It was also found that effects were much more pronounced on plants planted in the early summer after shoot growth had started. When planted at this time, untreated plants produced no new shoot growth during that season, but treated plants continued to grow vigorously. This effect could be of practical importance in preventing 'planting check' in some species, and this possibility is being examined by further experiments in the forest on 1958 plantings of beech and poplar.

Chemical Fire Retardants 432.331

Preliminary tests of sodium calcium borate and monoammonium phosphate for fireproofing vegetation have yielded promising results. Vegetation treated with these compounds failed to ignite when exposed to fires in field tests, and it seems likely that such materials could be of tactical value in rapid establishment of temporary fire breaks during fire-fighting operations. Equipment, costs and effectiveness of large-scale applications are now under investigation.

SILVICULTURAL INVESTIGATIONS IN THE FOREST

(B) SCOTLAND AND NORTH ENGLAND

By M. V. EDWARDS and G. G. STEWART

Replanting Areas of Recently Cleared Conifers 230.9

The area of woods which are sufficiently tall to be affected by windblow is increasing constantly. For this reason, and because in the near future felling in the normal course of management will begin, it is important to find a solution to various problems concerned with the replanting of first rotation woods. This is especially true in hill areas where the establishment of the first crop may not have been easy. Some of the questions which can be asked are these:

(*a*) Can a more exacting species than the one used in the first crop now be raised?
(*b*) Will the same species as was used before grow better or worse in the second rotation?
(*c*) Where ground preparation—for example, ploughing in peat areas for drainage and for the provision of turf for planting—has been necessary for the initial crop, is further preparation for replanting necessary?
(*d*) If it is necessary, how is it to be done?
(*e*) On upland heaths where ploughing for cultivation was carried out to begin with, is further ploughing necessary or possible?
(*f*) In areas where good drainage is essential, what is the most practicable method of altering a system of drains which was badly aligned at the time of the first planting?

A beginning has been made to finding the answers to some of these questions. Experiments at five forests in Scotland have been laid down to compare the growth of a number of species where the first crop has recently been felled. On each site the original species has been included in the range of species replanted. In two of these experiments cultivation by ploughing with a tine plough, hydraulically mounted on a crawler tractor, has been tried.

The same plough was also used in attempts to cut new drains in poorly drained felled areas in two Scottish Border forests. In each case the underlying soil was boulder clay, but in one case the clay was overlaid by 3–6 inches of humus or peat and in the other by 12 inches of peat. On the shallow peat site the roots from old stumps had some grip in the soil beneath the peat, which held the roots sufficiently well for the plough-share to cut through them; but in the deeper peat the roots were all in the peat itself and, having no firm hold, were not cut by the plough and whole stumps were pulled out. These stumps piled up under the plough and could not easily be cleared from the line of the intended drain. The same results were given in the cultivation trials mentioned above; one was on 12–15 inches of peat where the stumps were pulled out whole, the other was on a clay loam where the roots of the stumps were held sufficiently firmly to be cut by the plough.

The conclusion from this is that ploughing appears to be impracticable in stump-covered land where the roots lie only in the peat, that is where the peat is more than about nine inches deep. On shallow loams and very shallow peat over clay, ploughing for drainage or for cultivation, with a mounted tine, is possible. There is no doubt that the work puts a great strain on the plough and tractor and that the best machine has not yet been found. This emphasises the great importance of making sure that the drainage system is correctly aligned and of the right density when a crop is first established.

From observation of former replantings, it seems probable that allowing re-invasion of vegetation to take place before replanting is harmful to the young trees. Two experiments to test the effects of planting, in each of five years after felling, have been established.

In all the above replanting trials, the problem of the control of deer has been excluded by the erection of deer-proof fences around the areas; these fences would often be uneconomical in ordinary practice. Thus it is clear that practical and inexpensive methods of excluding deer temporarily from regeneration areas should be found. One experiment on the protection of young plants from deer using brashing debris has been established.

Afforestation Problems

Heathland 232.11:233

Trials of the less common species, planted in areas where normally only a few species are widely used, were continued.

A new experiment on a heathland site at Teindland Forest, Moray, was established. In this experiment a Forestry Commission tine plough, modified to throw a furrow simultaneously to the left and to the right, was used. The result on the level ground used for the experiment was very satisfactory, and almost complete covering of the heather vegetation was achieved.

Peatland 232.11:233

Lodgepole pine has been used in experiments on peat for 30 years, but it has almost always been used in mixture with other species which the pine was intended to nurse. Consequently there are almost no pure crops in the pole stage which could be used for further experiments, for example, thinning and manuring trials. With a view to providing areas of pure lodgepole pine, four separate 20-acre blocks of a south coastal provenance were established on deep peat areas in the South Scotland Conservancy.

Little is known of the effects of peat afforestation on the peat itself. A fairly large area (one square chain) of basin peat at Inchnacardoch Forest, Inverness-shire, isolated in 1928, has shown no shrinkage; but it seems clear that small blocks of peat, for example, the ridges turned out by a drainage plough, shrink considerably within a short time. Four trials on deep peat were established to study the amount of shrinkage which takes place after spaced-furrow ploughing using a draining plough, and planting with lodgepole pine.

Pilot Plots on Other Limiting Sites 232.11:233:425

The older pilot plots continue to grow slowly and most give promise of reasonable success. No new plots were established during the year, but a 30-acre block of pure lodgepole pine was planted at Naver Forest, Sutherland. This site is part of a large peat area which at present is classed as doubtfully plantable.

The plots established last year at Hebden Royd Forest, near Halifax, have made a good beginning. Their development in this area, where atmospheric pollution is great, will be watched carefully. In an attempt to isolate the factors of infertile soil and exposure, experiments were established at Hebden Royd Forest and on ground belonging to the Halifax Corporation Water Board (where pilot plots were established from 1951 to 1953). These experiments consisted of planting young trees in cardboard pots containing a good fertile soil; when the plants were well rooted, the pots were transferred to the experimental sites. Half the pots were inserted in the ground in the protection of a lath fence of about 50 per cent pore space, and the other half were planted without this protection. Two controls in a clean atmosphere but in exposed situations were established at Kielder Forest, Northumberland, and at Broxa in Langdale Forest, Yorkshire.

Age and Type of Plant 232.411

In 1945, one-year seedlings sufficiently large and vigorous to be considered for planting in the forest were first raised in heathland nurseries and on sterilised agricultural-type soils. Experiments to test these seedlings on ploughed land in various forests were commenced in 1946 and 1947 and were continued in 1948 and 1949 in many parts of the country.

Some promising results—and some failures—were obtained in the early series; but the work in 1948 and 1949 led to the realisation that, while many of the one-year seedlings were tall enough to plant, they were thin and spindly, and lacked branches. Because of this, measurements of the diameter of the root collar were made and its relation to the survival of the plants in the forest examined. These experiments were made on Sitka spruce, and the data for the first year in one forest were published on pages 22–23 of the *Annual Report on Forest Research* for 1949–50. These results have since been confirmed and extended up to an age of six years, by parallel experiments in two other forests.

Root collar diameters were not taken into consideration in all the 1948 and 1949 experiments, which included many different combinations of age and type of plant, but the results suggested a broad correlation between success (in establishment and growth over the first six years) and both collar diameter and the height of the plants, within the range of three to ten inches, when leaving the nursery. In terms of age and type of plant, the results of the different experiments were sometimes conflicting, and they have not been published.

A simple experiment was commenced in 1951 to compare one-year-old seedlings with normal one-plus-one transplants. Plots of 100 plants each were planted in pairs in each year's annual planting area in two forests for five years. Between 25 and 30 pairs were scattered over different site types each year, using the commonly planted species. Thus, Scots pine, lodgepole pine, Japanese larch, Norway spruce and Sitka spruce were included in varying proportions according to the type of ground being planted. Previous work has shown that seedlings are most likely to be successful in poor sites which have been ploughed, and where competition from weed growth is least severe. Therefore, one forest on the upland heaths of the eastern side of Scotland was chosen, and one forest on deep peat in the west (Fetteresso, Kincardineshire, and Glentrool, Kirkcudbrightshire). Results up to the age of three years have been summarised, and showed that losses in transplants rarely exceeded 20 per cent, so that beating up was hardly necessary, whereas losses in the seedlings ranged from 28–53 per cent and their use in normal practice is not advisable. The experiment will be terminated and the details published at the end of six years' growth.

During the progress of these 'age and type' experiments, work on undercutting seed beds in nurseries as a substitute for transplanting, soon led to an enquiry as to the desirable characteristics of a good plant for forest planting. Detailed studies were made of the height of the plants, both undercut or transplanted, at the end of two years in the nursery. Records were made of the following: the weight of the plant—root and shoot separately—the number of roots with secondary thickening and over two inches long, and the root-collar diameter. It was hoped that the weight of the shoot would give an indication of its branchiness, and the count of roots, which is very laborious to carry out, was made on account of the common belief that a fibrous root is desirable (see *Annual Report on Forest Research* for 1951–52, page 107).

These investigations have shown that root-collar diameter is highly correlated with shoot weight, root weight and number of roots; root weight and number of roots are also highly correlated. The value of the collar diameter as a measure of the physical characteristics of the plant is therefore clear, and this is especially useful because it is the only one which can be determined without disturbing a plant; furthermore it is easily measured. This work was encouraged by the paper presented by A. J. Rutter to the British Association at Oxford in 1954 (*Forestry*, 28, pages 125–35) which emphasised the importance of diameter measurements. The experiments were extended to the forest, and data were obtained with Scots pine and Japanese larch from two nurseries, planted in four forests in 1954. Tests of the regressions of the survival of the plants in the forest, on both collar diameter and the height of the plants when leaving the nursery, showed that, for Scots pine, both were significant or appreciable at all the forests, and that the principal component in the regressions was the collar diameter, demonstrating that survival may well be estimated best from collar diameter alone. For Japanese larch, the regressions were appreciable in some forests but nowhere significant. Probably none of the experiments was critical for this species.

Tests are now in progress with other species in a number of forests, and it is becoming evident that, within certain limits of height, root collar diameter is a critical factor in determining the success of a plant in the forest, particularly for survival and probably for subsequent growth. Collar diameter is an easily understood expression of the sturdiness of a plant, and the height and diameter of plants is probably far more important than the number of years they have stood in seed bed or transplant lines; possibly height and diameter are even more important than transplanting or undercutting. It is hoped that further experiments will enable foresters in this country, as in others, to set standards of height and collar diameter for different planting sites. Nurseries, which differ in climate, soil fertility, etc., will then be able to determine the ages and types of plants necessary under their own conditions to produce plants of the desirable standards.

Manuring in the Forest 232.425.1:237.4

During the year, many early experiments on the use of fertilisers on deep acid peat were closed. Among these was the oldest trial of mineral phosphate and superphosphate which had been laid down on the Lon Mor at Inchnacardoch Forest in 1928. The earliest experiment employing any kind of phosphatic manure, laid down in the same area in 1925, had already been used for other experiments in 1928. These experiments are now only of historic interest.

In the early days of this work, basic slag was the principal form of phosphatic manure, but it came to be replaced by ground mineral phosphate.

Recent experimental work on phosphate has been directed to the use of triple superphosphate instead of ground mineral phosphate, and the results of a series of experiments on this subject are also included in Part III, page 117. The importance of phosphate is such that last year each tree, on about 8,000 acres of new plantations in Scotland, was given a dressing of some form of phosphatic fertiliser; this acreage comprised one-third of the total area planted by the Forestry Commission in Scotland.

As regards the later stages, when the crop had closed canopy, investigations have been carried out by the Macaulay Institute for Soil Research into the nutrient content of the needles of several species of conifers. In certain cases on the poorer sites, there are indications that it may, by this method, be possible to discover which nutrients are in short supply. But on better sites there may be no critical nutrient deficiency. Fertiliser experiments are being laid down, in co-operation with the Macaulay Institute, on lodgepole pine and Sitka spruce on deep peat, where there are indications from needle analyses that potash and magnesium may be deficient; and also on better sites where deficiencies of nitrogen, phosphate, potash and calcium are suspected, in slow-growing crops of Norway spruce and Scots pine.

High Elevation and Other Woods on Exposed Sites 233

For some years trial plantations have been made at high elevations, and on very exposed sites at low elevations, particularly near the coast. Valuable information has been obtained from these trials, but it was thought that much could be learned from the numerous older woods on similar sites, most of which are privately owned. Consequently, a survey of high-elevation and other woods on exposed sites has been commenced. This survey has as its main object, to record the success—or lack of it—of different species, under varying limiting conditions, particularly varying conditions of exposure, and the recording of this information should give a valuable historical record. But it is hoped that other information will become available as a result of the records made; for example, it should be possible to make a much clearer evaluation of exposure over the country and perhaps to delineate a series of exposure zones.

Thinning 242

The laying down of an experiment in Norway spruce, to compare the type of heavy crown thinning developed in the South Scotland Conservancy with the more commonly-used moderately heavy low thinning, was completed. The yields of the first thinning are given in Table 8. The most interesting points seem to be the very different number of trees removed in the two different grades, and their average volume.

Table 8

Comparison of Two Types of Thinning in Norway Spruce 20 years old, Quality class III

(Forest of Ae, Expt. 18/57)

Thinning Grade	Yield from First Thinning				
	Number of trees removed		Average Q.G.B.H. (in.)	Average volume per measureable tree (Hoppus ft.)	Volume of measurable trees per acre over bark (Hoppus ft.)
	Measurable (2½ in. Q.G.B.H. and above)	Unmeasurable (below 2½ in. Q.G.B.H.)			
C/D	94	360	2¾	0·56	53
Heavy Crown	132	8	3¼	1·45	192

Notes: C/D = Low thinning, moderately heavy grade.
Heavy Crown = Crown thinning, heavy grade.
Q.G.B.H. = Quarter Girth at Breast Height.

PROVENANCE STUDIES

By R. F. WOOD and R. LINES

232.12

During this year, much time has been spent on the assessment of our older experiments, many of which are now reaching the stage at which yield data are becoming available. Since our coverage is now reasonably satisfactory for most of the important species, progressively less effort is being directed to general provenance enquiries, and new experiments are usually concerned with filling gaps in our knowledge, perhaps especially those related to the part played by provenance on special sites, where this factor has been little studied.

The following notes refer only to current activities, or studies which have yielded new or interesting information during the year. Only a few of the species on which we have provenance studies are mentioned.

Lodgepole Pine 232.12

Work has continued on the series of experiments planted prior to 1939, and the results will be published later. Five sample plots were established in selected provenances at Wykeham, Yorkshire, and these will not only add substantially to the number of permanent sample plots of this species, but will also provide a measure of the differences in yield to be expected between common provenances on the same site. For example, a plot of Prince George origin (northern interior of British Columbia), has a top height of 27½ feet and a total production of 1,140 hoppus feet over bark per acre at 20 years of age, while one from the coastal area of the Olympic peninsula, Washington, has a top height of 31 feet and a total production of 1,580 hoppus feet.

A provenance of lodgepole pine which has been widely planted in Scotland derives from one large seed importation in 1926, 200 lb. of seed from Alberta. The actual origin cannot be traced with certainty, but is thought to be the forests around Kananaskis at about 6,000 feet. This is one of the most easterly stations of the species in Canada, and the performance of the resulting trees in this country has been studied with interest. Many foresters have commented on the straight stem form and the lack of coarse branching of trees of this provenance and, because they seed rather freely, numerous cone collections have been made from stands of this Albertan origin. Over the past four or five years, however, reports have come in which suggest that this provenance is susceptible to needle discoloration, ill-health and even death under severe conditions of exposure, or where soil conditions are unfavourable. Similar symptoms have appeared on lodgepole pine of less continental origin, e.g., from the southern interior of British Columbia, where planted on unfavourable sites in exposed, highly maritime districts in Wales and Cornwall.

The Albertan provenance has not been planted in replicated provenance experiments, but plantations of it adjacent to such experiments suggest that it is a good deal less vigorous than the commonly-planted provenances from the southern interior of British Columbia.

An experiment commenced in 1950 compared another extremely continental seed origin of lodgepole pine, from Western Montana, with two seed lots originating from Lulu Island at the mouth of the Fraser River, British Columbia. (This latter origin was for a period a standard source of coastal lodgepole pine.) The particular experiment, though of little general interest, has been of some value in providing an example of seed size and other qualitative differences affecting the size of stock, as a confusing element in provenance work. The seed of the Western Montana lot was appreciably bigger than the two Lulu Island ones and it had a higher germination percentage. The mean height of the first-year seedlings of the Montana origin was mid-way between that of the two Lulu Island provenances, the poorest for height being "Lot A", and this also had the lowest germination percentage. By the end of the first year in the transplant lines the Western Montana plants had fallen to bottom place, but there was still an appreciable size difference between the tall plants of "Lot B" seed and the shorter ones from the "Lot A" seed. In 1952 they were planted out at Watten, Caithness; Achnashellach, Wester Ross; and Inchnacardoch, Inverness-shire, and the results of their subsequent growth after three and six years in the forest are shown in Table 9 overleaf.

In this particular case, nursery differences between the two Lulu Island seed lots have been nullified after a relatively short period in the forest, but this is by no means a general rule. The present comparison between the Western Montana provenance and the Lulu Island ones follows the normal pattern, the former exhibiting yellowish green needles and short horizontal branches, the latter with shorter darker green needles, and more upright spreading branches.

New experiments on the provenance of lodgepole pine were laid down, in the spring of 1958, on two sites in central Wales and three sites in south-west England. These are regions in which no proper trials have been previously conducted, but it appears from a number of fortuitous comparisons that seed origin of lodgepole pine is a particularly important matter in the more exposed

Table 9

Performance of Different Provenances of Lodgepole Pine at Three Sites

Heights in feet

Provenance	Watten		Achnashellach		Inchnacardoch		Mean	
	3 yr.	6 yr.	3 yr.	6 yr.	3 yr.	6 yr.	3 yr.	6 yr.
Lulu Island (Lot A) ..	1·8	3·1	1·7	4·0	1·7	4·2	1·7	3·8
Lulu Island (Lot B) ..	1·9	3·4	1·7	3·9	1·4	3·7	1·7	3·6
West Montana.. ..	1·7	2·8	1·2	3·2	1·2	3·3	1·4	3·1
Standard error of mean	0·04	0·1	0·1	0·1	0·04	0·1	—	—
Difference for significance: 5% ..	0·1	0·3	0·3	0·5	0·1	0·2	—	—
1% ..	0·2	0·5	0·4	0·7	0·2	0·4	—	—

coastal districts of Wales and Cornwall, and may become critical on the poorest sites. One of the Welsh sites is at Coed Taliesin, on steep grassy slopes with heather, *Calluna vulgaris* and gorse, *Ulex gallii*. The latter plant often typifies rather difficult conditions, and may become a very expensive weed if the crop fails to suppress it early, and this the more continental provenances of lodgepole pine usually fail to do. The other Welsh site is on a high-elevation peat. The English sites are all on extremely deficient soils; Croft Pascoe on the serpentine of the Lizard Peninsula; Wilsey Down near Bodmin Moor, a site on which unsuitable provenances of lodgepole pine have failed to close canopy; and Wareham Forest in Dorset.

The experiments include a number of seed origins from different latitudes on the coasts of Washington and Oregon—aiming here to discover whether there are any important differences inside what is now considered the standard seed source for coastal lodgepole pine.

Three provenances from the coastal regions of British Columbia are also represented; Lulu Island, a source which is now thought to represent a non-vigorous strain; Langley, from the Lower Fraser River; and Ladysmith, from the dry eastern side of Vancouver Island, where the tree often develops a very good form in dense stands following fires, and is commonly associated with Douglas fir. Provenances from climates intermediate between the oceanic coastal type and the truly continental, are represented by seed origins in the foothills of the Oregon Cascade Mountains, and a well known provenance from the southern interior of British Columbia—Shuswap Lake—is also included. In the nursery, the provenances from the Oregon and Washington coast, were markedly more vigorous than the rest, while the two provenances from the Cascade foothills were markedly less vigorous and had distinctly bluer foliage than all the others. (It is recalled that in a recent study Critchfield (1957) considered that lodgepole pine from the Cascade Mountains merited sub-specific rank.)

European Larch

Little is known in this country about the growth of Polish provenances of European larch, but what information is available suggests that further investigation of this seed source would be rewarding. The oldest individual trees are probably those of Professor Henry's collection at the Botanic Gardens of Kew, Edinburgh and Dublin, and the National Pinetum at Bedgebury. Plants of the same seed lot were planted at Drummond Hill, Perthshire, in 1926. The experiment is rather exposed and at 900 feet elevation. An assessment carried out in 1949 showed that the five surviving trees ranged in height from 33–49 feet, with an average of 40 feet, which was taller than Silesian and Tatra larch, but less than Japanese larch. They were noticeably more canker-resistant than Silesian larch or larch from the Central Alps. At Bedgebury there are several individual trees which have grown very well but with a tendency towards sinuous stems.

The oldest plot of Polish larch is undoubtedly the stand planted in 1935 on the Bennan Hill, Blairquhan Estate, Ayrshire. A full account of this was published in 1948 by Sir James Hunter-Blair (1948), who kindly allowed the Research Branch to carry out a further measurement in July 1957. This showed that at the age of 23 years it had a top height of 42 feet and a mean girth of 21½ inches. The basal area was 60 square feet per acre and the equivalent Quality Class was II. An adjacent stand of Darnaway, Morayshire, origin was poorer, equivalent to Quality Class III.

The next importation of Polish seed did not occur until 1949, when small lots of seed were received from three Polish locations: Skarzysko, Mala Wies and Gora Chelmowa. Similar quantities were imported from these areas in the following year. Stock raised from this seed has been planted over a considerable range of sites, some of which were selected because of the serious degree of "die back" experienced by previous crops of European larch, mostly of Alpine origin. Sites of this nature are at Drumtochty, Kincardineshire; Thornthwaite, Cumberland; and Coed y Brenin, Merioneth. The Skarzysko and Mala Wies provenances are represented at these forests (but not that from Gora Chelmowa), and comparative plots of Sudeten, Scottish and Alpine provenances are also represented; in addition there are plots of Japanese and hybrid larch. In these experiments, broadly speaking, the Polish larch occupy a position between the hybrid and Japanese larches, and the other European provenances, in respect of height growth. There are, however, several exceptions. At Coed y Brenin (Dolgoed), Polish larch from Skarzysko has grown faster even than hybrid larch, and all three Polish provenances grew faster than hybrid larch for the first few seasons on a high, exposed site at Drummond Hill, in an experiment which has since unfortunately been much damaged by deer. In one instance (only) a plot of Scottish origin from Farigaig, Inverness-shire has grown faster than Polish larch. This was in the Benmore Forest Garden.

For illustration, Table 10 shows the early height growth experienced at two sites at Coed y Brenin, where Polish larch has been planted in comparison with other European provenances, and also with Japanese and Hybrid larch.

The very fast growth of these young Polish larch plots has occasionally been accompanied by instability, trees a few feet high tending to fall over. The form of stem has also been generally rather poor, much inferior for instance to that of comparative plots of Scottish or Sudeten larch. Where comparisons between Polish provenances have been available, as at Savernake, Wiltshire, Drummond Hill, Perthshire, and Broxa, Yorkshire, there is general agreement that the Gora Chelmowa larch exhibits the poorest form. It is of interest to note that Bornebusch (1948) has remarked on the twisted form of trees of Gora Chelmowa provenance in Danish experiments.

Table 10

Heights of Larch at February 1958 on Two Sites Previously Occupied by Larch Affected by Die-back. Coed y Brenin, Merioneth

Id. No.	Origin	Year of planting	Pen-y-Bryn	Dolgoed
			Height feet	Height feet
49/259	Farigaig, Inverness	1951	4·5	—
49/230	Mala Wies, Poland	1951	6·1	—
49/56	Japanese larch	1951	8·4	—
49/260	Hybrid larch, 1st generation, Dunkeld	1951	7·7	—
50/66	Boga Wood, Altyre, Moray*	1952	3·44	—
50/66	Boga Wood, Altyre, Moray*	1952	4·6	8·8
50/141	Schlitz, Hesse	1952	4·6	8·7
50/252	Münsterthal, Switzerland	1952	3·7	6·8
50/67	Hybrid larch, Inver Wood, Dunkeld	1952	7·3	11·1
50/81	Millbuie, Moray	1952	4·8	8·0
50/265	Sudeten larch, Hruby, Jesenik, Moravia	1952	5·4	10·0
50/139	Skarzysko, Poland	1952	—	11·7

Note: * This plot was put in to replace a 1951 planting of trees from Strathconon, Ross, which failed to become established.

Sitka Spruce

Our oldest Sitka spruce provenance experiment planted at Radnor Forest in 1929, comparing Sitka spruce of Queen Charlotte Islands, Washington, Oregon and Californian origin, has recently been the subject of an investigation into the specific gravity of timber. This was conducted in collaboration with the Forest Products Research Laboratory, Princes Risborough. The primary object of the investigation was to find methods of analysing the data available from stands of different seed origin, site, or silvicultural treatment, and to derive regression equations, descriptive of the variation of mechanical properties inside the tree.

The specific gravity of the Queen Charlotte Islands spruce timber was generally higher than that of the timber of the three other provenances, but the differences were not great. Apart from this general difference in level, there were very appreciable differences in the pattern of distribution of specific gravity between provenances. It is hoped to publish an account of the statistical methods used in the analysis.

As this experiment is unreplicated, comparisons of growth and yield are not subject to estimates of site variation. It may however be of interest to examine the figures for height growth and standing volume obtained when the plots were measured in January 1956, as given in Table 11.

One of our more recent provenance experiments (planted in 1950), compares a number of seed origins from the State of Washington, and includes the "standard" seed source—Queen Charlotte Islands, British Columbia. It is established at Gwydyr, Caernarvonshire, Glendaruel, Argyll, and at Kielder, Northumberland. The two former sites are relatively favourable, and no frost damage of any severity has so far been observed.

Table 11

Height Growth and Standing Volume of Four Provenances of Sitka Spruce

Radnor Experiment 20

Provenance	Age	Top height feet	Standing Volume of trees, hoppus feet per acre, over bark
Washington	27	58	2,651
Oregon	27	67	3,308
California	27	60	3,202
Queen Charlotte Isles ..	27	52	2,298

At Kielder a peculiar discoloration of the needles was noticed in October 1954, and an account of the possible causes was given in the *Report on Forest Research*, 1955. A later assessment, comprising a complete count of all trees with dead leading shoots, showed some interesting provenance differences, and it is clear that the earlier damage resulted in extensive dying-back of the leading shoots in some of the provenances, as shown in Table 12.

Table 12

Variation in Percentages of Trees with Dead Leaders between Different Provenances of Sitka Spruce

Kielder Experiment 53

Provenance	Percentage of trees with dead leaders	Transformed percentage	Percentage of trees with lammas shoots	Percentage of trees with lammas shoots at Glendaruel
Section 1 (Latin Square Layout)				
Queen Charlotte Islands ..	6·6	14·7		3·3
Great Hoh River, Washington	64·8	53·8		15·1
Nemah River, Washington ..	65·0	54·1	Not	22·4
Columbia River, Washington ..	55·0	47·9	assessed	12·7
Grays Harbor, Washington ..	67·2	55·2		14·2
Standard error of means ..		± 2·7		
Difference for significance at 5%		8·3		
1%		11·6		
Section 2 (Random Block Layout)				
Queen Charlotte Islands ..	10·2	17·4	0·9	1·6
Harwood, Northumberland ..	2·8	10·5	0·2	—
Satsop River, Washington ..	57·8	46·2	10·6	16·9
Copalis River, Washington ..	65·8	50·4	14·4	12·4
Standard error of means ..		± 2·4		
Difference for significance at 5%		7·4		
1%		10·2		

It is clear that the provenance from the Queen Charlotte Islands (which is our main source of Sitka spruce seed), was highly significantly less affected by the discoloration and ensuing shoot die-back, than were the more southerly

Washington provenances. The Harwood provenance is from a stand at an elevation of 1,000 feet, originally planted with trees from Queen Charlotte Islands seed.

The fact that the needle discoloration was first noted in the autumn, suggested that frosts at that time of year, rather than spring frosts, were the probable cause, and it was observed that the Washington plants remained active and produced lammas shoots long after those from Queen Charlotte Islands had become dormant. The number of trees with lammas shoots was counted in December 1956, and includes only those trees which showed more than three lammas shoots, since it appeared in the forest that the trees fell naturally into two classes:

(*a*) those with numerous lammas shoots and

(*b*) those with either one or two weakly developed shoots or none.

In the complementary experiment at Glendaruel a full assessment of all provenances was carried out, in the autumn of 1956, using the same classification for lammas shoots. From these counts it can be seen that there were between four and ten times as many trees with lammas shoots in the Washington provenances as in the one from Queen Charlotte Islands.

Frost damage has long been regarded as the principal factor in the choice between Queen Charlotte Island and more southerly (e.g. Washington and Oregon) seed sources for Sitka spruce.

The use of a single proven seed source undoubtedly avoids complications and confers a great measure of safety. It is, however, probably true that a very significant proportion of the area planted to Sitka spruce could grow the faster Washington provenance safely enough, and a few chosen sites might be suitable for Oregon spruce. Questions of timber quality should of course be further studied before accepting the higher yields to be expected from the use of more southerly seed origins as an unmixed blessing.

Cryptomeria japonica

This species, the Japanese cedar, is of minor rank at the present time, though certain trial plantations show considerable promise. Recently the opportunity occurred to make a small study of the provenance factor in this species, which is known to exhibit a considerable degree of variation in its native habitat.

A collection of eleven provenances of *Cryptomeria* was planted in March 1958 at Glynn Forest near Bodmin, Cornwall, on a fertile site previously covered with laurel scrub. Nine of the provenances came from Japan, some seed having been supplied through the kind auspices of Professor Lindquist and some through Professor Asakawa. In addition, there was one lot of home-collected seed from trees in the Speech House Arboretum, Forest of Dean, and one lot of plants raised from cuttings taken from plants of *C. japonica* var. *sinensis* (the Chinese mainland form) growing at the Royal Botanic Garden, Edinburgh.

REFERENCES

HUNTER-BLAIR, SIR J., 1948. The Polish Larch. *Scottish Forestry* 1, pages 21–25.

BORNEBUSCH, C. H., 1948. Experiments with Polish larch in Denmark. *Sylwan* 92(1), page 8-21.

CRITCHFIELD, W. B., 1957. *Geographic Variation in Pinus contorta*. Harvard Univ., Cambridge, Mass.

POPLARS

By J. JOBLING

Varietal Studies

Varietal Trial Plots

232.12

During this year, planting of trial plots was carried out at Blandford Forest, Dorset; Clanna, Forest of Dean, Gloucestershire; Harling, Thetford Chase, Norfolk; Rogate Forest, Sussex, and Wynyard Forest, County Durham. A limited amount of beating-up was done at a few other areas, notably at Quantock Forest, Somerset, in plots planted since 1956. Twenty-two trial areas in different parts of the country have now been fully planted and of these 11 are of major importance.

Assessments were carried out in a number of older plots, at three areas in Scotland and three in Kent. The work is being extended to other trials where plots were planted before 1953.

Varietal Collection

The collection at present contains 357 clones, a net increase of 24 over the previous year. Most of those added were of the section *Tacamahaca* and were received from Korea and Russia. Some will be used in the Populetum and others will be reserved for breeding purposes.

Populetum

This contains 211 clones, an increase for the year of 19. The distribution of clones by botanical group is as follows:—

White poplars and aspens, species and hybrids	35
North American Black Poplars	13
European Black Poplars	17
Hybrids between European and North American Black Poplars	63
North American Balsam poplars, species and hybrids	26
Asiatic Balsam Poplars	12
Hybrids between Black and Balsam Poplars	38
Leucoides Section	7

Silvicultural Experiments

Age and Type of Planting Stock

An experiment was laid down, at Alice Holt Forest, Hampshire, to compare the survival and early growth of two-year-old and one-year-old sets. Their behaviour will be compared with that of rooted plants included in the experiment, which it is hoped will provide information on the possible use of one-year stool shoots surplus to those required for producing cuttings.

Preliminary results from experiments investigating the behaviour of different sizes of plant, of a range of ages and types, suggest that the very small sizes of stock, generally less than four feet tall in the case of rooted cuttings, while surviving almost as well as normal-sized plants, do not show the same vigour during the first two seasons after planting. This tends to confirm observations made in varietal plantings during the past few years.

Planting Treatments

Experiments investigating types of mulches and methods of application were again laid down. At Alice Holt Forest the effects of different mulch materials are being compared with the responses due to application of herbicides to the ground vegetation at time of planting, both being applied to eliminate weed growth around the tree during the establishment period. The mulches are of sisalcraft paper, bark shavings and cut vegetation, applied to both rooted and unrooted plants.

At Gaywood Forest, Norfolk, a second experiment investigating the effects of applications of conifer bark peelings on newly planted stock was laid down. In this, different depths of mulch are being compared, with and without a dressing of ammonium sulphate either to the soil surface before the mulch is applied or to the actual surface of the mulch. The first experiment on this site concerned with the use of bark peelings, planted in 1957, showed that during the first season a mulch of cut vegetation improved the health of the trees more than when a mulch of bark peelings was applied. Trees which received bark peelings, however, were healthier than those which did not receive a mulch of any type, and were slightly healthier than trees around which a used fertiliser bag was placed. Height growth during the first season was not affected by any treatment. It was also noted that the mulch of bark peelings, applied to a depth of six inches, completely suppressed weed growth surrounding the plant, and it is probable that rather smaller applications may produce the same degree of suppression.

Methods of Planting

A further trial was carried out on mechanical methods of preparing planting holes. At Alice Holt a screw drainer driven from the rear of a Fordson "County" tractor, was used for boring the holes. These were taken to a depth of 18 to 24 inches, and a diameter at the soil surface of about 24 inches, and thus approximated in size to the larger type of planting pit favoured by some growers of poplar. The time taken to prepare 80 holes by this method was about half that taken to dig the same number of pits by hand. Due to a proportion of the soil being thrown some distance from the hole by the rotary movement of the screw, however, considerably more time was taken to fill these holes than was taken when planting in the hand-dug pits, where the soil was immediately available. It should not be impossible to devise a means of retaining most of the soil around the perimeter of a bored hole, however, for example by attaching weighted hessian sacks to the chassis of the auger to enclose it during the boring operation. If this were adequate the method would appear to have definite advantages over hand digging when a particularly large-scale planting was to be carried out. The behaviour of trees planted in the bored holes is being observed, although earlier work has shown that they survive as well and increase in height at a similar rate to trees planted in hand-dug pits.

Spacing

Planting has started at Chepstow Forest, Monmouthshire, of an experiment designed to investigate the possible yield of pulp wood from poplar, when grown at close spacing on a short rotation. The experiment is sited on a felled woodland area, now bearing considerable coppice regrowth of several tree species and a small stocking of suckers of *Populus canescens.* This will be retained for pulp production. The poplars are at uniform spacings of 7 feet × 7 feet, 11 feet × 11 feet and 15 feet × 15 feet. The variety is *P. tacamahaca* x *trichocarpa* 32, a particularly narrow-crowned type which it is thought allows of a considerably closer spacing than would be the case with most other varieties. It is likely that this variety will also tolerate a greater degree of competition than the Hybrid Black poplars, such as *P. robusta* and *P. serotina*, as is probably the case with other North American Balsam poplars.

Treatments other than spacing will be considered, and it is expected that different rotations will be adopted for comparisons of yield, and that a proportion of the experiment will be felled so that the yield from poplar coppice can also be observed.

Distribution of Cuttings

During the winter months cuttings of eight standard varieties were disposed of as shown in Table 13.

Table 13

Disposal of Poplar Cuttings: Forest Year 1958

Populus species

Destination	*P. eugenei*	*P. gelrica*	*P. laevigiata*	*P. robusta*	*P. serotina*	*P. berolinensis*	*P. tacam.* × *tricho.* 32	*P. tacam.* × *tricho.* 37
Forestry Commission ..	740	1,200	750	650	1,740	—	400	100
Private Estates ..	3,272	677	1,577	2,272	2,372	477	1,802	1,097
Trade Nurseries ..	950	200	850	3,000	700	550	1,900	800
Govt. of Northern Ireland	—	—	200	300	100	200	200	200
	4,962	2,077	3,377	6,222	4,912	1,227	4,302	2,197

In all 29,276 cuttings were despatched, 5,580 to other Commission nurseries, 13,546 to private estates, 8,950 to the trade and 122 to the Northern Ireland Forest Service, as against 33,204 cuttings distributed the previous year. In addition gifts of cuttings of a number of non-standard clones were made to research workers in Belgium, Canada, Eire, Germany, Holland, Italy, Portugal, Sweden and Syria.

Bacterial Canker Investigation

The testing of clones for their resistance to bacterial canker has continued, the work being centred in a temporary nursery at Gaywood Forest, Norfolk. Trees of highly canker-susceptible clones were again planted at all the major trial areas, and inoculated with bacterial slime. By doing this it is hoped to establish a source of infection at each site, so that the disease status of the clones under trial can be observed.

FOREST ECOLOGY

By J. M. B. BROWN

Ecology of Corsican Pine in Britain 181

Advantage has been taken of the extensive, though commonly small-scale, planting of *Pinus nigra* about 25 to 30 years ago to examine the distribution of disease and dieback, in relation to environmental factors. Numerous plantations have been inspected in south-west and east Scotland, in north-east, north-west and south-west England and in Wales. From all these districts there have come reports of disease and dieback, usually in pole stage plantations, and field observations have been directed towards finding environmental factors common to the affected sites, but wanting in sites in south and east England, and locally in other parts of the country, where Corsican pine appears well suited. Although there are some apparent inconsistencies, which detailed instrumental observation might smooth out, the geographic and topographic distribution of disease suggests that the fundamental trouble may be that on cool cloudy upland sites in Britain growth is not completed, nor the shoots hardened off, before the time when the first frosts of winter may be expected.

At an early stage of the work it was found that stands prone to disease often show unsatisfactory exploitation of the soil by the roots; and it is the view of Mr. W. R. Day of the Imperial Forestry Institute, Oxford, that the relation between tree and soil is often a significant feature of Corsican pine dieback. In the past year increasing attention has been given to this aspect of the problem, and it is intended to examine in more detail the root development in a few good stands in southern England. A feature of behaviour on northern and upland sites is the relatively good performance on coarse-textured soils of free drainage, where also the root development may repay study.

The reaction of *Pinus nigra* to calcareous soils, which are widespread in some parts of Britain where Corsican pine is climatically well suited, is under observation on the Jurassic limestone in Yorkshire and on the Cretaceous Chalk in the south. Other aspects of the study which have a bearing on silvicultural practice are concerned with provenance of seed, the incidence of disease, and recovery in relation to the age of the stand. As regards provenance, it is evident on the one hand that trees derived from different lots of Corsican seed may differ considerably in habit of growth, and on the other hand that the different forms of *Pinus nigra* may differ in susceptibility to disease and dieback: but owing to the scarcity of precise locality data in the seed importation records, and the doubt whether certain lots were collected in Corsica at all, it may be very difficult to correlate these two observations satisfactorily. Seed from other parts of the range of *P. nigra* has been used in a few plantations, experimental or other, and there is no doubt that a few extra-Corsican origins may have a limited application in forestry practice in Britain. Since the British plantations of the first quarter of this century began yielding cones, the Forestry Commission and private owners have become less dependent on imported seed; and, insofar as cones are produced by healthy trees on upland sites, the resulting seed may help to solve the problem of finding a suitable provenance of *Pinus nigra* for these sites. Hitherto seed production on upland sites has been no better than might be expected, but the surviving stands, as they grow older, may well make a small but very significant contribution.

In one instance in Scotland some disease, accompanied by frost damage, was recorded in a five-year-old plantation, but in general disease does not appear until after the plantation reaches the thicket stage. The progressive dieback of shoots, associated, in most cases at least, with the fungus *Brunchorstia destruens*, then lasts for several years and may affect a considerable proportion of the trees. Usually the plantation then recovers, and there is no clear evidence of recurrent outbreaks. There is some evidence that close stands are more subject to disease than those which, because of rugged terrain, or delayed and incomplete replacement of failures, are irregular and open; and it appears that the reduction of the stand by disease may be a kind of self-regulatory mechanism, leading to a healthier environment for the survivors. Should these observations be confirmed, they may suggest ways of controlling the disease and of treating the diseased plantations. The substantial areas of Corsican pine where disease has occurred, and of younger plantations on sites where disease may be expected, make this an important issue.

Soil Survey 114.7

In Monmouthshire and the New Forest there has been collaboration with the Working Plans Officer in the soil survey of woodlands for which plans were in course of preparation, and in Tintern Forest expert advice was obtained from an officer of the English Soil Survey, who kindly spent several days in the field and assisted with the classification of the Devonian and Lower Carboniferous soils represented in the Wye Valley woods.

Beech Regeneration 231.31

In the Chiltern beechwoods the natural regeneration plots established in Queen Wood, Watlington, in 1952 were thinned again in February 1958, the original gradient in canopy density being maintained in the three treatments. The results of the 1956 beech mast were negligible in this, as in many other Chiltern beechwoods, and some enquiries about the reasons for this failure were made. There was clear evidence at Watlington that the destruction of nuts by voles (*Microtus agrestis*), of which the population reached its peak about autumn 1956, was the dominant factor. In several woods, however, seedlings appeared in quantity in May 1957, but the losses were more or less severe—in some instances catastrophic—during the hot dry weather of June. In these cases the decisive influence of topographic factors (particularly aspect) and surface soil conditions could be clearly traced.

FOREST SOILS

By W. H. HINSON 114

The demand for soil analysis from the various sections of the Research Branch remained constant at about 250 samples per year. The determinations required have been carried out on this material and on a number of samples outstanding from the previous year. During the winter, 1,257 samples of pine and spruce needles were received. This material, collected in collaboration with the Silviculture Section, is representative of most current forest manuring trials and the analysis should assist in the interpretation of the results. It is also hoped to demonstrate the applicability or limitations of foliar analysis as a diagnostic method for advisory purposes, and perhaps to contribute to the general picture of the nutrition of the species concerned.

Other work on forest manuring included laboratory studies of the ion exchange properties of forest soils, in relation to the retention of nutrient cations from fertilisers; interesting results were obtained (*Chemistry and Industry* 1958, 194–6). It was found that the adsorption of potassium or ammonium ions from these soils was greatly suppressed in the presence of the associated anions of the usual neutral fertiliser salts. Losses of nitrogen from fertilisers due to leaching may be reduced if hydroxides or salts of weak acids, or certain other materials, are substituted for the neutral salts. The initial concentration of solutes in the soil solution for equivalent applications is also reduced. Field work is being pursued to evaluate the practical significance of these findings.

The sand culture experiment with poplar (*Populus gelrica*) referred to in the previous report has been maintained, and will be continued for a further year. Its purpose is to test this method as a means of demonstrating major nutrient deficiency symptoms.

Long-term Studies of the Nutrient Relations of Forest Crops and Forest Sites

Studies based on foliar analysis have played an important part in the investigation of the nutrient relation of forest crops during the last decade or so. The results obtained are being applied as a method of diagnosis of nutrient deficiency here and elsewhere, but there remain certain limitations and difficulties of interpretation. Therefore analysis of the whole stand is desirable—such work on annual crops and tree seedlings has proved to be valuable. Theoretically this is a straightforward approach for the study of the nutrient uptake of forest crops, but there are few examples of such work. The formidable technical problems of sampling such heterogeneous material, and the excessively large number of sub-samples required, has so far severely limited the scope of such studies. An attempt is being made to overcome these difficulties by employing a mobile chipping machine and a rather larger mill than is ordinarily used for laboratory purposes. These facilities should reduce the number of sub-samples necessary to obtain reliable determinations of the nutrient content of forest crops. The aim is to produce estimates of the nutrient uptake of forest crops on an area basis. Stands of economically important species differing in vigour, on sites covering a range of fertility levels, should by this treatment yield the data for a sound background; the elucidation of specific questions in the field of site and crop nutrient relations may well follow.

FOREST GENETICS

By J. D. MATTHEWS, A. F. MITCHELL and R. FAULKNER

General Programme of Improvement

165.3:232.311

Having defined the objects of breeding, three stages can be recognised in a tree breeding programme. Good phenotypes are selected and, by vegetative propagation, are brought together into central collections called Tree Banks. Testing the selected trees then follows with the objects of identifying individuals with good genotypes and high combining ability. Finally there is the production of improved varieties (cultivars) in seed orchards.

This process is being used in the breeding of Scots pine, the larches, Douglas fir, beech and certain other species. The first stage, that of the selection, propagation and preservation of good phenotypes (Plus trees) is well under way and should be largely completed in 1960 or 1961. The testing of the selected trees has already begun and this work will rapidly expand in the immediate future. Later *Annual Reports* will contain an increasing amount of information about the results of controlled self- and cross-pollinations, and of progeny trials both in the nursery and in the forest. The opportunity is, therefore, taken in this report to summarise the progress made in building up the collection of material for breeding work.

Survey of Seed Sources 232.311.2

The object of this Survey is to locate suitable seed sources for current planting programmes so that the practising forester may know where to obtain seed of the best of the existing varieties. The greater part of the survey work in 1957 was in the South-West Conservancy of England and 34 additions were made to the Register of Seed Sources for England.

Selection of Plus Trees 165.62

The selection and propagation of outstanding phenotypes (Plus trees) and other trees of more specialised interest was continued. The total number of Plus and other trees of all species which have been marked and recorded is now 2,462. Table 14 gives the position by species on the 31st March, 1958.

Table 14

Selection, Registration and Propagation of Plus and Other Trees

Species	Selected and registered	Propagated vegetatively	Planted in Tree Banks
Scots pine	638	557	395
Corsican pine	81	52	46
Other pines	44	25	5
European larch	426	179	156
Japanese larch	112	65	32
Other larches	38	11	11
Douglas fir	412	269	127
Norway spruce	52	15	—
Sitka spruce	136	20	—
Other spruces	15	—	—
Silver firs	49	—	—
Western hemlock	29	9	—
Western red cedar	30	28	2
Other conifers	66	27	10
Total Conifers	2,128	1,257	784
Oaks (*Quercus robur* and *Q. petraea*)	155	14	—
Beech	97	54	32
Sycamore	5	2	—
Ash	32	12	—
Birches	32	19	—
Other broadleaved species	13	1	—
Total broadleaved	334	102	32
Grand Total	2,462	1,359	816

It will be seen that the pines, larches and Douglas fir make up just over two-thirds of the trees which have been selected and registered. One-quarter of the trees are Scots pine. Just over one-half of the selected trees have been propagated by grafting or by the rooting of cuttings and one-third are now established in Tree Banks.

Vegetative Propagation 232.328

Grafting, the rooting of cuttings and layering were again used to raise clonal material for inclusion in Tree Banks and Seed Orchards. The final total of grafts attempted during the spring of 1957 was 7,834; the total of successful grafts surviving to the spring of 1958 was 6,101, representing 413 parent trees. The overall success was 78 per cent and the figures for the main propagation centres were: Alice Holt, 1,895 grafts attempted and 70 per cent success; Grizedale, 4,114 grafts attempted and 79 per cent success and Bush Nursery, 1,825 grafts attempted and 82 per cent success.

Propagation by grafting was first attempted during the spring of 1949 at Alice Holt. In that year a range of grafting methods was employed on several species with the object of gaining experience. In 1950 just over 2,000 grafts were attempted, mainly in the open nursery, but in this and succeeding years great difficulty was experienced in the grafting of the small Scots pine scions from the older Plus trees selected in Scotland. This problem was gradually overcome when the glasshouses at Grizedale became available and were converted for grafting this type of material, and as the staff became more experienced in the art of grafting. In 1954 work began at Bush Nursery (Midlothian) and the benefits of having three diversified propagation centres each with specialist staff are becoming more obvious each year.

Table 15 shows the results during the past five years.

Table 15

Number of Grafts Attempted and Successful, 1953–57

Year	Number of trees represented	Number of grafts attempted	Number surviving to following spring	Percentage success overall	Notes
1953	271	9,076	4,054	44·7	Mainly Scots pine from trees lost in gales of Jan., 1953.
1954	255	10,360	5,896	56·9	Work began at Bush Nursery.
1955	386	11,596	8,038	69·3	90 per cent were done at Alice Holt, Grizedale and Bush.
1956	364	9,495	7,754	81·7	A successful year for all species.
1957	413	7,834	6,101	77·9	Older grafts of Scots pine and larches began to yield scions.

The increase in the overall percentage success from 1935 to 1936 is evidently the result of a combination of factors, the more obvious being the improved grafting technique and after-care, the greater experience of the grafters, the improvement in propagation facilities, and the improvements in scion collection and storage.

Table 16 shows that the improvement has been greater for some species than for others. The greatest increase has been obtained in the grafting of Scots pine and the larches, while the grafting of Douglas fir has always been relatively successful. On the other hand the after-care and transplanting of Douglas fir grafts has always been difficult and still remains a problem. The seasonal variation in the percentage success with beech grafting is of interest and is now being investigated, as it is of some importance in practice.

Table 16

Percentage Success in Grafting by Species, 1953–57

Year	Scots pine	European and Japanese larches	Douglas fir	Beech	Other species
1953	33	47	71	—	18
1954	65	39	91	75	44
1955	70	77	90	53	40
1956	87	75	84	88	58
1957	86	81	90	49	38

Notes: (*a*) These figures were obtained by averaging the results for both outdoor grafting and that done under glass.
(*b*) No beech grafting was done in 1953.

The other species, besides those named in Table 16, which have been grafted during the past five years include Corsican pine, Lodgepole pine, Norway and Sitka spruce, sycamore, ash, birch and elm. Of these, Sitka spruce has proved to be the most difficult to graft. This species can be propagated more readily by means of cuttings, although not without difficulties.

The collection and propagation of individuals of *Thuja plicata* with apparent resistance to *Keithia thujina*, continued in collaboration with the Pathology Section. The production of rooted cuttings of X *Cupressocyparis leylandii* was also continued.

Formation of Tree Banks

The establishment of the National Collection of Plus and other trees of two-needled pines, the larches, Douglas fir and beech continued during the year and a total of 816 clones have now been planted. The number of clones planted is given by species in Table 14, while Table 17 shows the location of each Tree Bank and the area of ground allotted to each species on 31st March, 1958.

Table 17

Location and Area in Acres of Tree Banks by Species

Location	Scots and other pines	Larches	Douglas fir	Beech	Total
Newton Nursery, Morayshire ..	7	½	7	—	14½
Bush Nursery, Midlothian ..	—	4	—	—	4
Alice Holt, Hampshire	1	—	—	—	1
Bradon Forest, Wiltshire ..	—	—	—	1	1
Rendlesham Nursery, Suffolk ..	1	—	—	—	1
Total	9	4½	7	1	21½

Testing the Plus Trees 232.1

The progeny of 37 plus trees of Scots pine were planted out at Torrie Forest (Perthshire). The raising of the progeny derived from controlled self- and cross-pollinations in the pines, larches, Douglas fir and beech was continued at Alice Holt and Newton Nursery in 1957.

Formation of Seed Orchards 165.4:232.31

Seed Orchards of Scots pine, European larch, Douglas fir and beech are being formed, both to produce seed and provide a means of further improvement of these species. Seed orchards composed of clones of European and Japanese larch are also being planted to produce seed of the first generation hybrid *Larix* x *eurolepis*. Table 18 summarises the present position and shows the area of seed orchards planted or in an advanced state of formation in various parts of Britain. Work is in progress at 16 sites totalling 174 acres.

Table 18

Area in Acres of Seed Orchards in Various Parts of Britain

Location (Region)	Scots pine	European and Japanese larches (*a*)	Douglas fir	Beech	Other species (*b*)	Total
East and Central Scotland	14	8	7½	—	½	30
South West Scotland	—	2	—	—	—	2
South East Scotland	12	9	5	2	—	28
South East England	8	12	5	7	3½	35½
East England ..	4	2½	—	½	—	7
North West England	—	1	—	—	—	1
Total	38	34½	17½	9½	4	103½

Notes: (*a*) All but 2½ acres of the larch seed orchards are intended for the production of F_1 hybrid larch (*Larix* x *eurolepis*).

(*b*) "Other species" include ash.

These seed orchards contain a total of 360 clones of Scots pine, 152 clones of larch, 163 clones of Douglas fir and 26 clones of beech. As the testing programme proceeds, and the inherent advantages or defects of the various parent clones are established, the grafted seed trees in seed orchards will be developing to the stage at which they are able to bear sizeable crops of well-filled viable seed. Parent clones (Plus trees) with inherent defects will be removed from the seed orchards leaving the remaining good genotypes (Elite trees) to produce seed of the new variety or cultivar.

Technique of Tree Breeding 232.311.3:181.8

In June 1957 a "Mist" Propagation Unit was installed in one of the larger, heated, propagation frames at Alice Holt. The unit is of the type developed by the National Institute of Agricultural Engineering in which an "electronic leaf" is used to control the supply of water which reaches the cuttings as a fine mist.

In a trial of the equipment, 34 per cent of cuttings of one clone of X *Cupressocyparis leylandii*, inserted in early June, had rooted by late September. This output was raised to 55 per cent by the application of a growth substance (Seradix No. 3). By comparison with previous experience with cuttings of X *C. leylandii* it is evident that the use of the mist propagation unit considerably increased the output of rooted cuttings three months after insertion. Cuttings which remained unrooted were in a very good condition, and at the end of the period under review (i.e. end of March 1958) considerable numbers of them were showing well developed roots. The better of the two rooting media employed consisted of a half-and-half mixture of a fine-grained Leighton Buzzard sand and granulated peat. A much coarser grade of sand is to be tried this year to improve the drainage characteristics of the rooting medium.

Phenological observations were continued during the year. The relatively short period of hot, dry and sunny weather during late June and early July was evidently sufficient to stimulate moderate flower-bud formation in the larches, Douglas fir, several species of silver fir, beech and oak.

Co-operation with Dr. P. F. Wareing and Mr. K. A. Longman of the Botany Department of Manchester University, who are working on problems of tree physiology, included the provision of grafted plants and of glasshouse space at Grizedale in which temperature, light and humidity can be to some degree controlled.

Other Work

A meeting of Forest Tree Breeders was held at Alice Holt under the auspices of Section 22 of the International Union of Forest Research Organisations. Twenty-two delegates representing 13 countries attended the four-day meeting.

J. D. Matthews represented I.U.F.R.O. at the meeting of the International Commission for the Nomenclature of Cultivated Plants in London and A. F. Mitchell was appointed to the Arboricultural Committee of the Royal English Forestry Society. Mr. R. Faulkner of the Silvicultural Staff in Edinburgh assumed responsibility for the organisation of Genetics field work in the North.

The flow of enquiries from Forestry Commission and outside sources continued, some 109 enquiries being dealt with during the year.

FOREST PATHOLOGY

By J. S. MURRAY

44.48

Experimental work on forest pathology was limited in scope in the past year, due mainly to the withdrawal of Mr. Peace from active research while engaged in writing a text-book. As a result, no new projects were initiated, though work continued on most of the existing ones. Work on *Fomes annosus*, causing death and butt-rot in conifers, was much widened in scope and is now the most important of the section's activities.

One hundred and thirty-six minor queries from state forests and 114 from private estates were dealt with. Advisory work tends to take up a fair proportion of the section's time and much of it is stereotyped, the same kinds of queries coming in at the same time each year. It is valuable from two aspects however: it gives a very good indication of the relative importance of the various disease agencies in any one year, and their variation from year to year, and it also helps to bring to light any unusual or unreported diseases.

The latter aspect was exemplified in 1957, when examination of diseased pine material from Wareham showed the presence of a fungus apparently not recorded as the cause of disease on pine in Britain. The symptoms on the needles and morphological characters of the organism suggested a fungus closely related but not identical to *Septoria acicola*, the cause of "brown spot" on *Pinus palustris* in southern U.S.A. This matter is still under investigation.

Lophodermium pinastri caused serious losses in many nurseries in 1957. The damage is usually evident in late winter and poses a difficult question as to the feasibility of lining-out plants in various stages of attack. Unfortunately also the sporadic nature of attacks by this fungus makes doubtful the economic justification for standard protective sprays. Many other queries were concerned with death of leading and lateral shoots of Douglas fir after planting out, or less commonly after transplanting. This type of damage appears to be due to dehydration caused by transpiration losses while the roots are still inactive.

Group Dying of Conifers

Further reports of occurrences were received, chiefly from the west of the country. Little experimental work was done, apart from the laying-down of two experiments concerning the influence of the time of year of lighting fires on the forest floor, on the incidence of *Rhizina inflata*, and the effect of other soil sterilising treatments on the disease. More observational work was carried out. It was found, for instance, that in a Sitka spruce stand the fungus could establish itself on a fire-site and kill all the roots on a nearby tree within two and a half years. The average annual rate of spread of groups, over a six-year period, was three yards radially.

Resin Bleeding of Douglas Fir

Little further work was carried out on this disease. No new reports were received during 1957, though there is no doubt that trees in affected areas deteriorated. Periodic observations were made on numbered plots.

Keithia Disease, Didymascella thujina, on Thuja plicata

Spraying trials are being undertaken following encouraging results in a first attempt. In addition, a scheme for the rotation of *Thuja* in nurseries was proposed and has been adopted in Scotland. This will avoid the presence in nurseries of more than one "age" of *Thuja,* thus obviating the risk of infection of seedlings from older infected plants. In addition the nurseries will not have carried *Thuja* for two years previous to the sowings, to obviate the risk of infection from fructifications in the soil or on detritus. In this way it is hoped to greatly reduce the amount of infections occurring early in the plant's life, and consequently the severe build-up of damage in the transplant. If such a scheme were successful, it might be supplemented by an appropriate spraying regime in the last year in the nursery, since there is some evidence that losses of newly planted stock have been due to the continuation of infection contracted in the nursery.

The work of Mr. Pawsey at Nottingham on the biology and over-wintering mechanism of *Didymascella* (reported in Part II, page 109) is very relevant to out attempts at control.

Defoliation of Pines

Severe needle cast of pines by *Lophodermium pinastri* has become increasingly common in the last few years. Many reports were received, during the winter of 1957, of losses in nurseries, and some enquiries were made regarding protective spraying which has never become standard practice in Britain against this fungus.

There were fewer outbreaks of *Sclerophoma* in 1957 than in the previous two years and little opportunity was given for observing the association of this fungus with the pine gall midge.

Melampsora pinitorqua, Twisting Rust of Pines

After several attempts had failed to establish infection in a mixed planting of various two-needled pines and aspens at Alice Holt, successful infection of both pines and aspens was observed last summer. This followed the transference into the plot, of aspen leaves during the previous winter from an infected area. Typical lesions were seen on shoots of Scots and maritime pine but not on Corsican pine. No infection was seen on *Pinus resinosa* or *P. radiata.* Uredial leaf spots occurred heavily on *Populus tremula,* not at all on *Populus grandidentata* and *Populus tremuloides*—two of the American aspens—and moderately on *Populus tremula* x *tremuloides.* Inoculations of the aspen species with aeciospores from the pines supported these results.

The value of this test-bed in giving information on the susceptibility, or otherwise, of different aspen and pine species to the rust is already evident from these preliminary results.

Cronartium ribicola

Further additions were made to the *Ribes-Pinus* test-bed at Alice Holt. Apart from this no further work was done on the disease.

Botrytis cinerea on Nursery Conifers

Spraying experiments showed that *Botrytis* can be controlled by a wide variety of fungicides, provided that a protective spray is applied before infection takes place. The material giving best results was a formulation of tetramethyl thiuram disulphide, applied at about four pounds of active material per acre. Many of the queries in autumn concerned *Botrytis* damage, reflecting the need for a method of controlling this fungus.

Wound protectants

The most likely substances from previous trials were used in a wound protectant experiment on pruned beech at Westbury Forest. Even after the preliminary screening, these were found to vary in effects after one year. The experiment was designed so that further substances can be added to it as they come to hand.

Elm Disease, Ceratostomella ulmi

In this disease we are chiefly concerned with propagating, and planting out for testing, resistant clones from Holland. Additions were made to the three trial areas and further graftings were made in the nursery at Alice Holt. The natural infection existing in the trial areas was reinforced by artificial inoculation of trees not under test.

Meria laricis on larch

No work was done on this disease apart from co-operation with Mr. Biggs who is working on the biology of the fungus at Southampton. Severe defoliation, especially of European larch, was reported on nursery stock during the summer of 1957.

Decay and Death due to Fomes annosus

The survey was continued, and protection of selected forests is now being started in all Scottish and Welsh Conservancies. The infection status in these is generally more advanced than in England, but the intention is to institute protection in all Conservancies by the end of 1958, and then to progress towards a more general application, omitting only special classes of site. Creosote continues to be the main protectant, although polyborchlorate is now being used in East Anglia. Trials of a wide range of other alternative materials have been laid down.

During the course of the survey it has become apparent that not only butt-rot and death are important, but the windblow attributable to root-rot is becoming increasingly so. There is clear evidence of the increase and spread of the fungus, and good reason for anticipating its entry into most of our conifer crops (in the absence of protection) during the course of the present rotation. It has also been confirmed that the present scale and distribution of infection is mainly associated with our past conifer history, and that the presence of stumps and the availability of spores are the crucial infection factors.

Experiments have been laid down to check on the relative efficiency of various stump protectants, the efficiency of crop protection, other ways in which infection may occur (extraction damage, pruning wounds, infected fencing material), eradication measures, delayed thinning, and the resistance of silver firs (*Abies* genus) to *Fomes* attack. These are mainly long-term experiments, the results of which will not be available for some time.

The economic losses due to *Fomes* decay are being studied in conjunction with Mr. H. Dowden at Aberdeen University.

Polyporus schweinitzii

Little actual work is being carried out on this fungus, but many records of damage due to it have been collected during the course of the *Fomes* survey. Severe and very rapid development of rot in stems has been observed in many coniferous species. It seems to be particularly damaging on Douglas fir, and this is unfortunate in view of the resistance shown by the latter towards *Fomes*. The literature on *Polyporus schweinitzii* has been reviewed and it seems that very little is known of its biology and infection mechanism.

Armillaria mellea

Decay due to this fungus has been increasingly noted during the course of the *Fomes* survey work. Decay damage is normally limited to the immediate base of the tree, and its main importance is as a precursor of other decay fungi and in the occurrence of windblow associated with the extensive root-rot. The attack is found mainly in spruce on old hardwood sites. Its occurrence does not yet appear to be widespread enough to justify a change in the choice of species.

An experiment has been laid down to test methods of changing the substrate value, to the fungus, of hardwood stumps, by carrying out girdling, poisoning and hormone treatments of the trees prior to felling. The area will be replanted with a selection of conifer species susceptible to *Armillaria* attack, and assessments will be made of deaths.

FOREST ENTOMOLOGY

By MYLES CROOKE and D. BEVAN

The Pine Looper, Bupalus piniarius

Pupal Survey 453

The same areas were surveyed in 1958 as were covered in the previous year (see 1956 *Research Report*). The returns showed that throughout the country population levels are low, with counts of one or fewer pupae per square yard being general. In only two forests were counts slightly higher than normal, but in neither case does the population density give rise to immediate concern. The figures for Tentsmuir are commented upon in a following section. The other forest concerned, Rendlesham, is one in which in previous years a tendency towards slightly higher-than-average counts has been evident. This year is no exception in that out of the 17 compartments surveyed, four yielded population indices of between five and seven pupae per square yard.

Study Plot

A further full year's sampling has been carried out in the study plot located in Compartment 128 of the Elveden beat of Thetford. A number of modifications in sampling technique have been introduced, but the general approach remains basically the same as that described in considerable detail in the 1957 *Report on Forest Research*. The population level of *B. piniarius* has again fallen in the study area, and the pupal count in April 1958 was only 0·5 pupa per square yard. Dealing with such small numbers presents, of course, considerable practical difficulties in accurate sampling but even so, for most stages of the life cycle, the methods appear satisfactory. The early larval stages, however, cannot be adequately sampled by present methods, and consideration is being given to this problem.

Control Operation at Tentsmuir

In the *Report on Forest Research* for 1957 it was pointed out that the pine looper pupal counts made at Tentsmuir, earlier in 1957, were high and indicated probable infestation in 1958; a summary of the pupal counts was given.

The possibility of a population collapse before the damaging larval stage was reached could not, of course, be disregarded, and it was for this reason that further assessments of the population were planned. It was decided, firstly, to determine the success of adult emergence and, if necessary, to follow this with egg counting. Figures for adult emergence were obtained by placing traps, each one square yard in area, on the forest floor and making daily collections of the hatching insects. The figures showed that about 60 per cent of the pupae hatched, and some 30 per cent of these were females. Thus, at this stage, the population had not met with any serious setback. Egg assessments were started in the third week of July, on sample branches taken from randomly selected trees. Some guidance on the interpretation of results was to be had from the Continental literature, where a figure of 2,000 eggs per tree is commonly taken as a population demanding control measures. Having regard to the age, low quality class, and thin poor crowns of the pine at Tentsmuir, it was considered that for safety this figure should be reduced, and 1,000 eggs per tree was accepted as the critical figure. Altogether 15 compartments with a total area of 363 acres were found to have egg populations in excess of 1,000 per tree. These were treated when it had been established that egg hatching was complete.

In view of the small area involved, and the nature of the forest, the "TIFA" (Todd Insecticidal Fog Applicator) was selected as a suitable machine for the job. D.D.T., with its low mammalian toxicity, relative cheapness, and known efficacy against the larvae of *B. piniarius*, was an obvious choice of insecticide. A "forest fogging" formulation containing this chemical was specially prepared for this operation by Plant Protection, Ltd. The application rate decided upon was 1 lb. D.D.T. per acre.

In addition to the assessments, the only other preparatory work required was the cutting of racks within the compartments to allow access for machine and tractor. These racks were spaced at 100 to 150 yard intervals so that swathes of the same width could be treated at each run. The treatments were made at night when the obligatory condition of "climatic inversion" is most likely to occur. The operation, which was carried out during August, was most successful, as reference to the 1957/58 pupal counts in Table 19 show, but it did take longer than had been anticipated owing to the instability of the weather. In fact, of the 18 nights spent "standing-by to fog", on only five was it possible to do actual fogging, a total of 27 hours being actually spent on the application itself.

Table 19

Population Counts of Pine Looper Moth at Tentsmuir Forest

Cpt. No.	1956–57 Pupal count per sq. yd.	1957–58 Pupal count per sq. yd.	Post-treatment larval drop* per sq. yd.
72	23·6	NS	NS
77	32·6	0	NS
78	42·0	NS	213·0
79	56·0	0	136·4
82	40·2	NS	184·4
83	40·2	NS	167·6
84	32·4	NS	139·1
88	32·0	0	120·0
89	49·6	0	NS
90	27·4	NS	105·6
91	28·6	0	NS
92	49·2	NS	NS
93	17·8	NS	NS
98 (small part)	6·8 (av. over whole)	NS	NS
99	72·4	0	81·6
100	26·8	NS	178·6

0 = None. NS = Not sampled.

* These figures do not include those individuals caught in the crowns, which may be considerable in number. The counts are of use for checking fog coverage, but of little significance in testing the efficiency of control. They are included here for interest only.

The above table of pupal counts and larval drop data shows that the kill must have been very high. No healthy pupae were found in any of the treated compartments which were subsequently sampled. Comparison between treated and untreated areas is not possible, drift having affected the population in untreated compartments in the neighbourhood of the treated block. However, it is interesting to note that in one part to the south-east, well clear of the treated area, a small group of compartments had counts of four pupae per square yard in the 1957/58 survey. This figure is well above that commonly taken as endemic and, although not dangerous, it does suggest that the uncontrolled population is in no way a degenerate one.

Parasites

The studies on *Campoplex oxyacanthae* Boie., *Heteropelma calcator* Wes., and *Cratichneumon nigritarius* Grav. have been continued with material obtained from the extensive pupal survey and also from the Elveden study plot. Some progress has been made with the biological studies on *C. oxyacanthae* and *H. calcator*, but *C. nigritarius* still proves a most difficult subject. Not only is the species at present rare in, and difficult to obtain from, field populations of *B. piniarius*, but it is also difficult to handle under laboratory conditions. In view of the acute scarcity of British material of this species, arrangements were put in hand to import specimens from Germany so that the biological studies can be accelerated.

Semasia diniana Guen.

Investigations have continued on *Semasia diniana* in the infested areas of Hope Forest, Derbyshire, where approximately 229 acres of Sitka spruce plantation have been affected during the course of the outbreak. In addition, attacks on a lesser scale occurred on Corsican pine, Lodgepole pine and Japanese larch crops. The main objects of the study were, firstly, to collect data on the biology of the moth and, secondly, to appraise the effect of factors of natural control.

General information has been collected on the biology of this species by field observations and by laboratory rearings. Most interest centres on the host tree preferences of the moth, which appear to be erratic. In other parts of Europe larch is considered to be the main host; in a previous attack in Scotland, pines were most heavily attacked, whilst spruce was only slightly attacked and larch remained free of infestation. The larvae collected in Hope Forest morphologically resemble the Continental pine-feeding form. Thus it is obvious that the situation is a confused one. Further work will be dependent on the availability of material and at present it appears almost certain that the attack will not persist at a sufficiently high level to allow much more to be done.

This reduction in the level of infestation is due in great measure to the increasing impact of factors of natural control which became marked during the 1957 season. Firstly, a bacterial disease of the larvae was widespread, and in some parts of the area produced complete mortality. Secondly, predation by Syrphid larvae was heavy, and it appeared that the rather high aphid populations which were present favoured the build-up in numbers of these predators, of which five species were identified. Thirdly, parasites were active. Eight species of these were reared and the following complete or partial identifications made: *Apanteles* sp., *A. lineipes* Wesm., *A. jucundus* Marsh., *Meteorus* sp., *Campoplex* sp., *C. ? tumidulus* Grav., *Ephialtes eucosmidarum* P., *Phaeogenes osculator* Thnb., and a Pteromalid. In addition, a large ectoparasite was numerous, but it could not be reared in the laboratory and accordingly no identification could be made. Finally there was evidence, such as low egg viability and smaller-than-average pupal size, indicative of intrinsic degeneration of the population.

Studies of Conifer Sawflies

The larch sawfly survey was again carried out in 1957. The results are summarised below by species.

Pristiphora erichsoni Htg.

The population indices for this species are obtained by counting the number of larval clutches which can be found in selected sample areas. Although considerable changes in clutch numbers, as compared with these for 1955, were recorded in various localities, the overall density of population remains low. In nine forests the counts showed a decrease, and in six forests an increase, as compared with 1955.

Anoplonyx destructor Bens.

The survey revealed that all of those forests where populations had been high or moderately high in 1955 had lower counts in 1957. Conversely, but with two exceptions, forests with low population densities in 1955 showed an increase in numbers. The highest level of population recorded this year was in an area near Blair Castle on the Atholl Estates where the index had risen from the 1955 figure of 9·7 to 35·7. In no case, however, was very severe defoliation, such as had been present in 1955 at Radnor, Clashindarroch and Drumtochty Forests, recorded in 1957.

Pristiphora laricis Htg.

Only minor fluctuations were recorded in the generally low population levels of this species. Fourteen forests showed a decrease in population and only three an increase.

Laboratory studies on various species of conifer feeding sawflies have been continued on a small scale.

Tests with "Swingfog"

In pursuance of the general policy of testing machines which give promise of being useful in forest insect control operations, two trials were conducted in 1957 with the "Swingfog", a lightweight and portable fogging machine. One trial, against *Semasia diniana*, was sited at Hope Forest and had the twin objectives of testing the apparatus, and of creating a disinfected buffer zone between infested plantations of poor growth and crops of better growth into which the attack was encroaching. The second trial, against *Anoplonyx destructor* at Radnor Forest, was for testing purposes only.

At Hope Forest, two-thirds of a gallon of a 15 per cent D.D.T. solution was applied per acre to give an approximate dosage of 1 lb. of D.D.T. per acre, the treatment being timed to coincide with the peak of larval migration amongst the crowns of the host trees. Assessments after treatment disclosed that it had resulted in only a very slight reduction in the population. This failure to achieve a high mortality can be attributed to the fact that the larvae feed, within flushing buds or in silken webs, in well-protected situations. Further, owing to the fact that the machine was not operating efficiently, it proved difficult to control the droplet size of the fog emission. This in turn precluded the application of a fog of fairly large droplet size which would possibly have produced a higher mortality by residual poisoning.

At Radnor Forest, against the larch-feeding sawfly *Anoplonyx destructor*, one gallon of a 10 per cent D.D.T. solution in oil was applied per acre to give, again, an approximate dosage of 1 lb. of D.D.T. per acre. In this trial, assessments showed that the kill obtained was higher than in the preceding one but that the treatment did not achieve a good level of practical control. Once again the mechanical efficiency of the Swingfog was unsatisfactory, and in particular the fluctuating output was troublesome. It is proposed, despite these initial discouraging results, to continue testing this machine since it has some decided advantages over other types of applicators, particularly for dealing with small outbreaks in difficult terrain.

Trials of Insecticides Against the Pine Weevil, Hylobius abietis L.

Some additional assessments were made in the experimental plots referred to in the 1957 *Report* but by the end of the present year formal experiments had been discontinued. The results of these studies have allowed for practical recommendations for the insecticidal protection of newly-planted conifer crops against pine weevil attack being made, and the main interest now centres on follow-up observations, in user trials being conducted in various parts of the country.

Advisory Work

One hundred and forty-four enquiries were dealt with during the year, 78 originating from Forestry Commission and 66 from private sources.

Overseas Visit

M. Crooke visited Canada from April until October 1957 as a Nuffield Foundation Travelling Fellow, to study the organization and activities of the Forest Biology Division, Science Service, Department of Agriculture.

STUDIES OF GROWTH AND YIELD

By A. M. MACKENZIE and J. M. CHRISTIE

52

With the formation of the Working Plan and Economics sections mentioned in the 1957 *Research Report*, the main task has been the provision, from existing data, of a number of mensurational aids for the use of these new sections. The results of some of this work have already been published, whilst a number of other papers are being prepared for publication. The maintenance of existing permanent sample plots has continued and a limited number of new ones have been established.

Yield Tables and other Tabular Aids

The provisional yield tables for oak and beech, briefly mentioned in the 1957 *Report*, have been published (Forest Record 36. H.M.S.O. 2*s*. 6*d*.). With the exception of certain local yield tables, these are the first general yield tables for these two species to appear in Great Britain since those of Maw (1912).

A feature of the oak yield tables, for which an exact explanation is not known, is the culmination of the mean annual increment of the oak between 70 and 75 years, in all quality classes. This implies that the age of maximum volume production (the age when the current annual increment equals the mean annual increment) is approximately the same in all quality classes. This is contrary to what has been normally found to occur in crops of oak or other species elsewhere, where the point of maximum volume production is reached at successively later ages as the quality classes become poorer. It is, therefore, interesting to note a similar occurrence in a yield table for oak in Czechoslovakia, by Korsun, that has recently reached this country. In Korsun's yield table, which gives five quality classes, mean annual increment reaches its maximum at between 50 and 55 years in all quality classes. Total volume production is greater than that in Britain in the upper quality classes, but is somewhat less in the lower ones; height growth appears to be much faster in the early years in all quality classes than in this country, but it slows down considerably after 100 years of age. (Korsun 1956.)

No further conifer yield tables were published, but work has started on the preparation of a yield table for *Abies nobilis*. For this species, three quality classes are recognized with heights at 50 years of age of 80 feet, 70 feet and 60 feet. These are the same as the first three quality classes of Norway spruce, but the early height growth of *Abies nobilis* appears to be rather slower than that of spruce of the equivalent quality class.

To facilitate the study of the economics of growing coniferous crops, the present yield tables are being extended to show the development of each species under thinning regimes both lighter and heavier than those given in Forest Record No. 24, *Revised Yield Tables for Conifers in Great Britain.* It is hoped that by the use of mathematical methods, as opposed to the empirical and graphical methods formerly used, the construction of these additional tables will be greatly speeded up. The tables will be published by species, or groups of species, as they are completed.

The 1957 *Research Report* described the use of alignment charts for the estimation of the standing volume per acre of conifers, when top height and basal area per acre are known. Charts have now been prepared for oak and beech as well, and all have been combined into a single publication (Forest Record No. 37, *Alignment Charts and Form Height Tables for Determining Stand Volumes of Conifers, Oak, and Beech.* H.M.S.O. 1*s.* 9*d.*) These alignment charts have proved particularly useful for working plan enumerations.

Another extension to the published yield tables for conifers, which has been started, is the preparation of *stand tables.* These tables will show the distribution of trees by quarter girth classes, for given mean quarter girths.

A problem requiring urgent attention, mainly for working plan purposes, is a simple but reliable method of forecasting volume increment per acre in stands of young fast-growing conifers. Yield tables can be used direct when the conditions in the stand in question are similar to those shown in the tables, but in stands that have undergone a considerable period of check before closing canopy, or in stands where height growth has markedly slowed down, estimates of increment made directly from *current* height growth alone may prove more reliable. This method was first described by Hummel and Brett (1950) in the *Empire Forestry Review,* the increments quoted in that paper have been revised to correspond with those in the conifer yield tables and are given in Table 20 below.

Table 20

Volume Increment per Acre for Every One Foot of Height Growth by Height Classes and Species

Top height (feet)	Volume Increment per acre in hoppus feet over bark for every one foot of height growth (From the *Revised Yield Tables for Conifers in Great Britain*)								
	Scots pine	Corsican pine	European larch	Japanese larch	Norway spruce	Sitka spruce	Douglas fir	Western hemlock	Abies grandis
21–30	75	100	55	60	80	85	55	85	55
31–40	122	144	72	86	130	115	97	124	106
41–50	147	156	87	101	162	137	118	139	135
51–60	170	171	100	111	191	149	132	156	160
61–70	190	179	113	120	214	154	144	173	175
71–80	202	188	125	129	231	157	152	189	182
81–90	—	—	134	136	—	158	163	204	187
91–100	—	—	142	—	—	160	170	—	189
101–110	—	—	—	—	—	162	177	—	190

Because of the difficulty of accurately measuring current height growth, this method is not always satisfactory. For this reason we are now trying to improve on existing methods of estimating increment from increment borings, and to find a method which will be easy to apply, and which will take into account the rapid changes of height growth that occur in these young coniferous stands over comparatively short periods of time. Trials have started, but it is too early to report much progress.

The paper by Finch (1957), describing new ways of using the general tariff tables, first mentioned in the 1956 *Research Report* was published as Forest Record No. 32, entitled *New Ways of Using the General Tariff Tables for Conifers.* (H.M.S.O. 1*s.* 3*d.*).

Permanent Sample Plots

The measurement and establishment of permanent sample plots continues, 48 new plots were established during the year, 23 in England, 16 in Scotland and 9 in Wales, whilst 7 plots were abandoned because of wind damage. The total number of plots now managed by the section is 767, of which 403 are in England, 230 in Scotland and 134 in Wales. A total of 146 plots were re-measured, 71 in England and Wales and 75 in Scotland.

More than half of the new plots were established in stands of the less common conifers such as *Tsuga heterophylla*, *Abies grandis*, *Abies nobilis* and lodgepole pine. Four of these plots established in a stand of *Abies nobilis* in Dovey Forest in Merioneth comprise the first thinning series for this species. The study of the growth of beech in the Chilterns was continued and a further six sample plots were established there; five more permanent sample plots were established in the forest plots at Bedgebury. Of the new plots in Scotland, the most interesting are a set of six established at Glen Urquhart Forest, Inverness-shire, in the following species, *Tsuga heterophylla*, *Abies grandis* and *A. nobilis*, *Picea omorika*, lodgepole pine and Douglas fir.

The code of sample plot procedure which has been discussed in previous years is now being printed as a bulletin. (F.C. Bulletin 31, in the press.).

Other Work

As in past years, miscellaneous activities have occupied a considerable amount of the time of the section. No new instruments have been tested. A paper by Finch, reviewing the development and application of angle gauges (relascopes) and the literature on the subject was published in *Forestry* in 1957. The development of a new Swedish caliper, called a Lignometer, is being watched with interest.

Co-operation has continued with the Utilisation Development section and with the Forest Products Research Laboratory at Princes Risborough. One assistant forester is now stationed at the Forest Products Research Laboratory and is assisting with tests of home-grown pit props. So far, over 1,000 Scots and Corsican pine pit props have been tested; the next species to be tested are Norway and Sitka spruce props from the Border forests. In addition to this work, a further 11 batches of timber were sent to Princes Risborough. Samples of bark have been collected from a number of forests for an investigation into the tannin content of the bark of various species.

Members of the section have given lectures and have arranged field demonstrations of thinnings and methods of volume estimation, as well as continuing to give demonstrations of the tariff method of measurement to conservancy staffs. There has been no great increase in the number of enquiries dealt with; of the 280 received, about one-third were from members of the public or from overseas.

REFERENCES

MAW, P. TRENTHAM. *Complete Yield Tables for British Woodlands and the Finance of British Forestry.* Crosby Lockwood & Son, London, 1912.

KORSUN, ING, DR. F. Porostni Tabulky Pro Dub. *Pracé Vyzkumných ústavů Lesnických C.S.R.*(11), 1956 (251–278).

HUMMEL, F. C. and BRETT, I. A Simple Method of Estimating Volume Increment in Stands of Young Conifers. *Empire Forestry Review*, Vol. 29, No. 1. 1950, pages 58–59.

FINCH, H. D. S. Plotless Enumeration with Angle Gauges. *Forestry*, Vol. 30, No. 2. 1957, pages 173–192.

CENSUS OF WOODLANDS

By G. M. L. LOCKE

524.6

During the past year the field work in the counties of Cumberland, Westmorland and Devon was completed and the results are now being computed. This field work involved the resurvey of about 170,000 acres of woodland.

The main task, however, was to produce an up-to-date assessment of the area, volume and increment of the woodlands in Great Britain as a basis for a major review of felling policy both in private and Forestry Commission forests. The position was ascertained partly from the results of the Census Revision of recent years and partly from Conservancy records showing annual fellings, plantings and other relevant information. A detailed report of this work is being prepared for publication but a provisional summary of some of the results is given below.

The total area of woodland in Great Britain in blocks of one acre and over in extent is just over 4 million acres. This means that woodlands now cover about 7·1 per cent of the land area in this country, compared with 6·4 per cent in 1947. Despite this increase, Great Britain is still one of the most lightly wooded countries in Europe.

Out of the total area of 4 million acres, about $1\frac{1}{4}$ million acres or slightly less than one-third are composed of Forestry Commission woodlands and this holding is increasing annually. In the past ten years, in fact, the area of Forestry Commission plantations has more than doubled. By far the greatest proportion of this increase has come from the afforestation of bare land, but a considerable area has also been planted on unproductive woodland areas which have been acquired by lease or sale from private owners. Only a small proportion of the increase is accounted for by the acquisition of plantations.

The private woodland area has shown a decrease in the past ten years, largely as a result of the purchase of unproductive woodlands by the Forestry Commission, but although the total area has decreased the productive area of woodlands under private ownership is increasing.

Table 21 shows the distribution of the total area of 4 million acres by Forest Type.

Table 21

Total Woodland Area by Forest Type, 1957

Woods of One Acre and Over — Area in Acres

Forest Type	Area in acres	Per cent of Total
HIGH FOREST		
Mainly Coniferous	1,570,000	39
Mainly Broadleaved	890,000	22
Total	2,460,000	61
Coppice and Coppice-with-Standards ..	330,000	8
Unproductive Woodlands	1,220,000	31
Total	4,010,000	100

High Forest accounts for 61 per cent of the area, with coniferous woodland making up almost two-thirds of this total, coppice types account for 8 per cent and the unproductive categories, i.e. scrub, partially felled and felled woodland make up the balance of 31 per cent. The area of unproductive woodland has dropped by about 150,000 acres in the last ten years, as a result of reafforestation, but the large area which remains gives some indication of the problem of rehabilitation which still faces us.

As a result of the large-scale afforestation, carried out mainly with coniferous species, by the Forestry Commission during the past 35 years, and the greatly increased pace of private planting, with both conifers and hardwoods, during the past ten years, the age class distribution is now becoming very unbalanced. The majority of the coniferous crops are under 40 years of age, most of the older crops having been felled during the two wars, whilst the broadleaved crops are predominantly classed as over 80 years or as uneven-aged, and the area under 40 years of age is relatively small.

Table 22 shows the present age-class distribution of High Forest crops in Great Britain.

The primary timber demand in this country is for softwoods and this is reflected in current planting trends. In the 1 to 10-year age-class, conifers account for 90 per cent of the area, but in spite of this a greater area of broadleaved species has been planted in the last ten years than in any decade since 1900.

Estimates of total timber volume are set out for Great Britain as a whole in Table 23. The totals for High Forest, Coppice with Standards and unproductive woods relate to 1957, whilst the data for Hedgerow and Park Timber relate to 1951 as no new data are available.

Table 22

Age-Class Distribution of High Forest in Great Britain, 1957

Woods of One Acre and Over | Area in thousands of acres

Composition	Age Class																			
	1–10		11–20		21–30		31–40		41–60		61–80		81–120		121 and over		Uneven		Total	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Mainly Coniferous	670	43	230	15	270	17	160	10	80	5	50	3	40	2	10	1	60	4	1,570	100
Mainly Broadleaved	80	9	20	2	20	2	30	4	60	7	80	9	100	11	100	11	400	45	890	100
Total ..	750	30	250	10	290	12	190	8	140	6	130	5	140	6	110	4	460	19	2,460	100

For the first time we are able to give some indication of the probable size-class distribution of the timber volume in this country. This has been done by analysing the results of about 3,000 1/10th acre plots which have been measured in High Forest and Coppice with Standards during the course of the Census Revision.

Table 23

Total Volume, and Size Class Distribution by Type, 1957

All Categories — Millions of Hoppus Feet

Category	Standing Volume	Size Class Distribution			
		6 in. B.H.Q.G. and under	$6\frac{1}{4}$–9 in. B.H.Q.G.	$9\frac{1}{4}$–12 in. B.H.Q.G.	Over 12 in. B.H.Q.G.
Mainly Coniferous High Forest	1,280	430	390	220	240
Mainly Broadleaved High Forest Coppice and Coppice with Standards	1,350	90	170	250	840
Total High Forest Coppice and Coppice with Standards ..	2,630	520	560	470	1,080
Hedgerow and Unproductive Woods	880	40	60	90	690
Totals ..	3,510	560	620	560	1,770

Note: B.H.Q.G. = Breast-Height Quarter-Girth.

Table 23 shows clearly the preponderance of small-sized timber in the conifers and the preponderance of large-sized material, mainly over 12 inch B.H.Q.G., in the hardwoods.

The review of the present position has afforded a suitable opportunity for considering the future of census work, and to adapt it to changing conditions. Drastic changes have been decided upon. Instead of continuing to do a complete census in a limited number of counties each year, at a rate which will enable the country as a whole to be covered in about 15 years, it is proposed to close down all field work for about 6 to 10 years and then to undertake a survey, on a sampling basis, of the country as a whole. The new procedure, which will reduce field work to about one-tenth, will be equally effective in providing a general summary of the situation for the country as a whole. It will not give the additional information provided by the continuous census revision on the changes taking place each year, nor on the position in individual forests both under State and private control, but this detailed information is now largely available from Conservancy records and need no longer be collected as an integral part of the Census work.

WORKING PLANS

By D. R. JOHNSTON

62

This report deals with the first complete year's work of the new Working Plans section, which has initially been concerned rather with the mechanics of collecting and presenting data for working plans than with the more fundamental problems arising from the use of the data in forest management. This preliminary work may conveniently be discussed under four main heads.

The Working Plan Code and the Maps Code

The Working Plans Officer attended all the meetings of the Working Plan Committee and the Maps Code Committee, and has acted as a liaison between the two. He co-operated with the local District Officer in writing a draft plan for Dovey Forest for the Working Plan Committee. The section has been particularly concerned with the methods of presenting field survey data in the working plan.

Working Plan Techniques and Procedures

Procedures for preparing working plans are being worked out to ensure that routine work is standardised, that the various jobs are tackled in the right sequence, that the work of specialist field staff is integrated with that of the local forest staff, that the work is completed quickly and economically, and that a satisfactory standard is maintained. Experience alone will lead to improvements in this aspect of working plan surveys.

The first working plan surveys undertaken by the section were based upon the census procedure. This was found to be not entirely suitable, and as a result new methods of describing the growing stock have been introduced and a new sub-compartment assessment form designed for the recording of descriptive data in the field.

A revision of the basic map and stock map will become a routine operation in future working plan surveys. Current survey methods were thought to be unsatisfactory, and accordingly the Ordnance Survey has been consulted about ground survey and the Directorate of Overseas survey about air survey. An officer from the Ordnance Survey has examined our conditions, and has come to the conclusion that our survey problem is very similar to that of the small-scale revision of the Ordnance Surveys; arrangements are being made for the Ordnance Survey to train a number of Research Branch and Conservancy foresters in graphical survey methods.

In collaboration with the Directorate of Overseas Surveys, a preliminary stock map was prepared for part of Queen Elizabeth Forest using aerial photographs. Photographs on the scale of 1: 20,000 were enlarged to 1: 10,000 and, without reference either to the existing stock map or to a new Ordnance survey of the rides and roads, a new map was prepared for part of the area. This was subsequently compared with the revised Ordnance Survey six-inch sheet, and with the crops on the ground. It appeared that about 80 per cent of the re-survey necessary had been accomplished from the air photos, although a subsequent ground check would have been necessary to produce a reliable map.

In our pole-stage conifer forests, estimates of increment and in particular estimates of probable future increment, are generally of more immediate importance than estimates of standing volume; but where estimates of standing volume are needed, they are only of very limited value unless they are given by size classes. For the purposes of forest management, it is preferable to know the volume by size-classes of a species, or a group of species, within the forest, rather than to know the standing volume, undifferentiated into size classes, of each sub-compartment. For these reasons it has been found expedient to spend less time on getting estimates of the standing volume of each sub-compartment and to rely more upon stratified random sampling for estimates of volume and increment for the forest as a whole. In the sample plots, all trees are girthed, and an objective sample of every *n*th tree is measured for height. The volume is calculated by using the general tariff tables, in conjunction with either the general volume tables or the alignment charts. Estimates of increment are derived from yield tables, by allocating the plot to a quality class and making a scaled adjustment to the yield table figures, according to the actual basal area of the plot.

Preliminary attempts at soil classification and mapping were made during the year in the New, Tintern and Chepstow forests, in collaboration with the Ecologist and the Soil Survey of England and Wales. But the full value of soil mapping will only be achieved when the information on soil is integrated with that of the other factors of the environment, and the whole related to tree growth. Further development in this direction cannot be undertaken with our existing resources.

Liaison with Other Departments

A closer liaison than has hitherto existed has been developed with the Ordnance Survey, the Soil Survey of Great Britain, the Geological Survey, the Ministry of Housing and Local Government, the Department of Health for Scotland and the Directorate of Overseas Surveys. Apart from getting much useful advice, we have received access to unpublished information that will be of use in the preparation of working plans.

Working Plan Field Work

Working Plan surveys have been completed for Ratagan Forest (Inverness and Ross), the New Forest (Hampshire), Tintern and Chepstow forests (Monmouthshire) and are in progress at the Forest of Dean (Gloucestershire), Thetford Chase (Norfolk), Cairn Edward (Inverness-shire) and Ae (Dumfries).

FOREST ECONOMICS

By A. J. GRAYSON

901

As part of the training of the economist, the latter part of the year under review has been spent at Oxford where economics in the wide sense, and unrestricted in content to problems of forest economics, is being studied. This course has been undertaken with the aim of equipping the economist with a fuller understanding of the methods of economic analysis, as well as of the place of forestry in the national economy. Work has continued in the field of surveying, collating and assessing the information at present available for economic analysis, and also on the particular question of the nature of the demand, the characteristics of the markets, and the conditions of supply for hardwood timbers. In this connection a start has been made on the collection of data on prices and consumption of hardwoods in the country in past years.

A paper has been prepared (for publication in the *Empire Forestry Review*) on the desirable density of forest roads for extraction purposes. It is shown that while no great variation in total extraction cost may occur over a rather wide range of densities, optimal values vary widely under different conditions of yield, relative costs of intermediate haul (by tractor or horse), and road-building. Some clear conclusions may be drawn: namely that on the basis of present knowledge the desirable degree of capital investment represented by roads needs to be, and can be, calculated with some degree of assurance, but notions of a generally applicable optimum density are fallacious.

The utility of modern electronic computors has been demonstrated in calculations of profitability in even-aged plantations. These calculations are rather laborious when undertaken by ordinary methods, and rapid and numerous computations on fast computers open up the possibility of preparing "ready reckoners" for the determination of costs of production and financial yield. Some work has been done on the algebra of profitability calculations, and this has proved valuable in connection with questions of policy of current interest.

DESIGN AND ANALYSIS OF EXPERIMENTS

By J. N. R. JEFFERS

0—015.5

In the year under review, the work of the Statistics Section has been mainly devoted to that of advising all Sections of the Research Branch on the design of their experiments and sample surveys, and to the analysis and reporting of the experiments and surveys completed. The improvement of the service that can be offered to these Sections has been regarded as having priority over all other aspects of the work of the Statistics Section, with the result that it has been possible to undertake only a very limited amount of research into the application of statistical methods of design and analysis to the problems of forest research and management. As a result, however, the Section is now organised to deal more rapidly with the current statistical work of the Research Branch, and has been able to reduce the delays experienced in analysing and reporting the results of experiments and surveys.

A limited amount of advisory work on the problems of the design and analysis of forest experiments has also been undertaken for Colonial Forest Departments, and for other organisations and research stations interested in forest problems, e.g. the Forest Products Research Laboratory, and the Colonial Products Laboratory.

The Statistician visited Cyprus, at the request of the Cyprus Forest Department, from 27th April to 20th May, 1957. The main purpose of this visit was to design experiments on possible methods of re-afforestation of the extensive areas of forest burnt in recent years, but the opportunity was taken to discuss the special factors to be taken into account in the design of forest experiments in Cyprus, and the needs of the Forest Department in the continued development of efficient experimental methods.

Two members of the Section have attended courses on the programming of the Ferranti "Pegasus" Computer, in order to study the application of electronic computing to the analysis of data arising in forest research. The experience gained during these courses, and subsequently, has affected profoundly the organisation of the Section. The application of digital computing to the analysis of data arising from forest experiments and surveys is, however, discussed in greater detail below.

Experimental Design

Designs have been provided for more than sixty experiments during the year, and both the number of experiments designed and the diversity of these experiments continue to increase from year to year. Greater stress has been laid on the exact specification of the hypotheses which are to be tested by each experiment, in order that the planning and design of the individual experiments can be achieved with maximum efficiency and economy, and to ensure the concentration of the analysis of results on essentials. In addition, the individual experiments have been linked by project plans, which explain the background of the project, and the place of each experiment within its context.

Designs involving fractional replication, which were introduced for the first time last year, have proved to be of particular value in the early stages of investigations for testing the effects of simple interactions of as many factors as possible. Their use has been extended to large-scale experiments designed to test the effects of fertiliser applications of six elements on the growth of pole-stage crops.

Survey Design

There has been a variety of sampling problems, including surveys of insect populations, strength of pit props, forest accidents, and the stocking and growth of forests. The survey of the strength of home-grown pit props has continued throughout the year, and is based on sequential sampling from regions which produce considerable quantities of props. The information which has so far been obtained has confirmed the economy of this method of sampling, and has given valuable results in a relatively short time.

A particular study has been made of the problems of sampling forest crops in order to determine the physical, mechanical, and chemical properties of the timber. The results of this study will enable new investigations into these important aspects of forest utilisation to be designed with greater efficiency.

Analysis of Experiments and Surveys

Analysis of 260 experiments and surveys, representing 1,200 individual analyses, have been undertaken. Most of these analyses were carried out on desk calculating machines, but some of the more complex analyses were completed with the aid of the "Pegasus" Computer.

The advantages of using electronic computers for the analysis of data arising from forest experiments are:

(1) The results of the analyses can be obtained in a shorter time, thus minimising the delay between the assessment and interpretation of the results of an experiment, and also helping to reduce the seasonal peak of

statistical work which is inevitable in research on agricultural, horticultural, or forest crops.

(2) The entire analysis, including the printing of the results in the correct layout, can be programmed so that typed sheets of the results can be dispatched immediately.

(3) Additional computations, which are not possible when the results are computed by desk machines, can be undertaken, e.g., tables of residuals, multiple covariance analysis, and multivariate analysis.

These advantages make it inevitable that the main weight of the analysis undertaken by the Section should eventually be placed on computers.

Programmes are at present being written for two main types of analysis. The first of these is a standard computing programme for the analysis of variance, which can be used for the analysis of data arising from factorial experiments. This programme will enable data from a wide variety of designs to be analysed with a minimum of programming, and will be applicable to about 60 per cent of the present work of the Section. Optional modification of the programme will be included, enabling transformations to be employed, or missing values to be calculated. The second type of analysis, for which programmes are being written, is that of multiple regression and correlation, applicable to a wide range of problems arising in forest mensuration and forest utilisation.

Research is continuing into the analysis of experiments on perennial crops by methods which describe the continuing growth of the trees as a growth curve.

Standardisation of Measurements and Tests of Instruments

The Working Party of Section 25 of the International Union of Forest Research Organisations is studying the problems of standardisation of the conventions of measurement in forest experiments, and of the collection and publication of information on instruments used in forestry. In co-operation with this Working Party, a questionnaire on the conventions of measurement adopted by the Research Branch has been completed, and a provisional list of instruments which have been described in English forestry literature has been compiled.

Multivariate Analysis

The use of electronic computing has made possible the application of multivariate analysis to forest problems, and a special study has been made of these methods in the past year. In particular, methods of component analysis, orthogonalised regression, canonical regression, dispersion analysis, and discriminant functions have proved to be of value. Three main studies have so far been undertaken:

(1) The analysis of those characters of nursery seedlings which influence their survival when planted in the forest.

(2) The analysis of the physical properties of pit-props which influence their strength.

(3) The analysis of the relationships between the dimensions of trees and the times taken to fell, trim, peel, and extract them.

MACHINERY RESEARCH

By R. G. SHAW

0—087

The number of machines that are available to improve productivity in the forest continues to expand. Many of these machines on the commercial market have been tested and covered by reports. Progress made on individual development projects is as follows:

Nursery Operations

All the main nursery operations have now been mechanised to a large extent, though variations in local conditions mean that the machines are often used with minor modifications. How many of these variations are really necessary, and not prompted by individual preference or established custom, is not yet known; but standardisation is an outstanding need if machinery is to pay a full dividend. Complete nursery mechanisation must, in any case, still be regarded as in the experimental stage for some time to come, since subsequent growth of machine-produced plants will have to be proved over a number of years. A machine carrying six Holland transplanting units, and lining out six rows at once, with the operators under cover from the weather, has been used successfully during the 1957-58 season.

Extraction and Conversion of Forest Produce

A self-propelled sulky has now been produced in prototype form. The machine lifts a half-ton log at the point of balance and is driven by a 288 c.c. engine. This method of transport has proved very effective on reasonably level ground, but over rough country too much physical effort is at present required from the operator to maintain control. Further development is in hand.

British-made power saws are making progress in design, and there is every indication that there is not long to wait for the much-needed saw with an engine of at least 75 c.c. and a total weight of under 25 lb., complete with chain and with all tanks full.

A very light mobile pendulum saw is now available which, when used with a portable conveyor system, may greatly increase the output of small forest conversion depots.

Bark Peeling

No new machines have been produced during the year. There are still three British-made machines in the portable class and some improvements have been made in various details.

Clearance of Derelict Woodland

There is on the British market a very wide range of machines designed to clear scrub vegetation of all kinds from hand-propelled motor-scythes up to heavy cutting and grubbing blades on tracked tractors. Some of the smaller machines have been tested on the weeding of young plantations. The results indicate that in comparison with the accepted form of hand weeding these machines show little saving in cost, but they do destroy virtually all the unwanted vegetation, whereas the hand method only removes vegetation immediately round the plant and the worst of the rest. Tests in 1957–58 suggested that this complete removal of weed growth by machine would result in a reduction in the number of subsequent weeding operations. If this can be proved beyond question on several weed species, the case for these machines would be a strong one. Further experiments are taking place. The large machines are all tractor-mounted, and consist of either a form of flail or cutting blade driven from the tractor power take-off, or a static blade on the front of the tractor. Great progress has been made in the design of all these larger machines, and many of them can give a most spectacular and effective performance.

Drain Clearing

The operation of cleaning an existing drain is very different to that of cutting an original drain, since cleaning must often be done in an existing plantation. Machines do exist which will clear agricultural drains very well, but they are all tractor-mounted and so are unable to reach many of the existing drains inside plantations. A new light machine is under development using a power-driven bucket and chain carried on a large diameter wheel in the drain bottom. The first field trials have been very encouraging, but difficulty is being experienced in controlling the machine in the drain. Further work is in progress.

Tractors

New tractors which appear to be suitable for forest work are tested at the Forest Research Station and subsequently submitted to an endurance trial on normal forest work. One new tractor was tested during the year.

Winches

Some of the newest winches are designed to fit onto the three-point linkage of standard tractors instead of being bolted onto the frame or transmission. The great attraction of these linkage-mounted winches is that they can be fitted in under ten minutes, or removed and the tractor restored to normal in the same time. The tractor can thus be used as a multi-purpose machine. Trials on one of the latest types have given a line pull of 12,000 lb. Further development on portable winches has resulted in a winch weighing 204 lb. with a line pull of 1,300 lb. at a speed of 88 feet per minute. This winch is easily carried by two men and can be anchored to the ground in a few minutes.

Ploughs

A recent development is a plough designed in light alloy for use in soft peat. This plough originated in Eire and a sample has been imported for trial in the Border country.

The tine plough is now being used very successfully, with a double mouldboard throwing to both right and left to suppress weed competition.

UTILISATION DEVELOPMENT

By E. G. RICHARDS

Home-Grown Pitprops 833

An investigation into the compressive strength of home-grown softwood pitprops has been started, in collaboration with the National Coal Board and the Forest Products Research Laboratory. The scheme will cover peeled props of Scots pine, Corsican pine, Norway spruce, Sitka spruce, European larch and Japanese larch. Both unseasoned and seasoned props will be tested.

Thinnings House 833

Following the satisfactory performance of the two-roomed office which was erected at Santon Downham in 1954, plans have been made to erect a three-bedroomed dwelling house at Joyden's Wood near Bexley in Kent. The house has been designed by the Timber Development Association, Ltd., who are acting as the Commission's architects.

The framing has been cut from Scots pine thinnings, and pressure-treated with a water-borne wood preservative. The exterior cladding, which will receive periodic brush treatment with a preservative finish, has been cut from thinnings of Scots pine, Sitka spruce and Japanese larch. The interior walls will be lined with plaster board backed with aluminium foil. According to tests carried out by the Building Research Station, the thermal insulation of this type of construction is slightly superior to that given by an 11-inch cavity brick wall.

Fence Post Trials 831.5

Experiments mentioned in the 1957 *Annual Report*, for determining the life of fencing posts treated with one or other of two wood preservatives, under various conditions of soil and climate, have gone ahead. The posts have already been driven at nine sites in Scotland provided by the Scottish Colleges of Agriculture and the Hill Farming Research Organisation, and at 11 sites in England and Wales provided by the Ministry of Agriculture, Fisheries and Food.

In Scotland, posts of birch and Sitka spruce 5 feet 6 inches long by 3 to 4 inches top diameter were used; one-third were treated with a proprietary water-borne preservative, one-third with creosote, and the remainder were left untreated to act as controls.

In England and Wales the experiment has been laid down on similar lines, the species used being Scots pine (at all sites) and one of the hardwoods likely to be available locally such as birch, sycamore, alder, ash and elm.

Extractives from Wood and Bark 866.4

Further determinations of the tannin content of conifer barks were made by the British Leather Manufacturers' Research Association. Some 24 analyses were made of Norway spruce bark, and the average tannin content was found to be 13·8 per cent, the non-tan content 14·6 per cent and the red colour 3·7 units. It is now clear that the poor results given by this species (described in the *Research Report* of 1956) were largely due to the failure to dry the bark immediately after collection.

More analyses were also made of Japanese larch bark, European larch bark, and Western hemlock bark.

An experiment was undertaken at Alice Holt and Gwydyr forests to determine the rate at which Sitka spruce tan bark deteriorates when left on the felled log. Poles were felled and snedded during the first week of June, and samples of bark were collected, dried, and sent to the British Leather Manufacturers' Research Association for analysis 3, 6, 12 and 24 weeks after felling; the results are not yet to hand.

Bark in Horticulture 892.49

Machine-peeled conifer bark is being tried as a mulch for fruit trees in Hertfordshire, and for poplar at Gaywood and Creran Forests. Details of the work with poplars are given by J. Jobling on page 59.

The Harvesting of Sitka Spruce Bark 866

Between the first week of May and the first week of September work was carried out on the cost of harvesting Sitka spruce tan bark at Mortimer, Hafod Fawr, Kershope, Harwood and Greskine forests.

At each of these forests, lengths of 4 feet 6 inches were marked off on freshly snedded poles, starting at the butt and continuing to the 3-inch top diameter point. The poles were then girdled with a timber scribe, and whole cylinders of bark were removed from between the girdles, using Forest of Dean type oak bark strippers. The time taken to peel the poles in this way was recorded. Records were also kept of the time taken to peel similar poles using an ordinary bark peeling spade and without collecting the bark.

The 4 feet 6 inch lengths were laid on the forest floor with the inner bark uppermost, for a period of three hours, for the initial drying to take place. They were then rolled up into "sticks" and placed in racks at the ride side for final drying. The sticks of bark were weighed daily and were considered to be air-dry when they had fallen to 55 per cent of their fresh weight. It was found that the bark would achieve this weight under favourable conditions in about 48 hours; under less favourable conditions, it took about two weeks.

Table 24 below gives the extra cost of removing the bark in cylinders over the cost of normal peeling with a peeling spade.

The Seasoning of Small Hardwood Logs 847.1

The experiment referred to in the 1957 *Report on Forest Research*, on the drying of small-sized hardwoods, has now been completed; the results are given on page 160.

The Use of Timber in Building 833

Further visits were made to building sites to make observations on the quality of timber used in the building of traditional houses. The work was done mainly in Northumberland, Durham, Gloucestershire and in Inverness-shire.

In each region, timber used for the carcassing and joinery of traditional houses under construction, was examined. Notes were made on the incidence of knots, wane, and other defects; and also on the category into which the timbers would fall if they were classified under the grading rules described in Forest Products Research Leaflet No. 49, *Grading of Sawn British Softwoods.*

Arrangements have been made to extend the survey.

PLATE 1. Edwards: Three Races of European Larch: Münsterthal provenance, Switzerland, Includes many small cankered trees.

PLATE 2. Edwards: Three Races of European Larch: Sudeten provenance, Silesia. Vigorous; note tendency to wavy stem form, and fine pendulous branching habit.

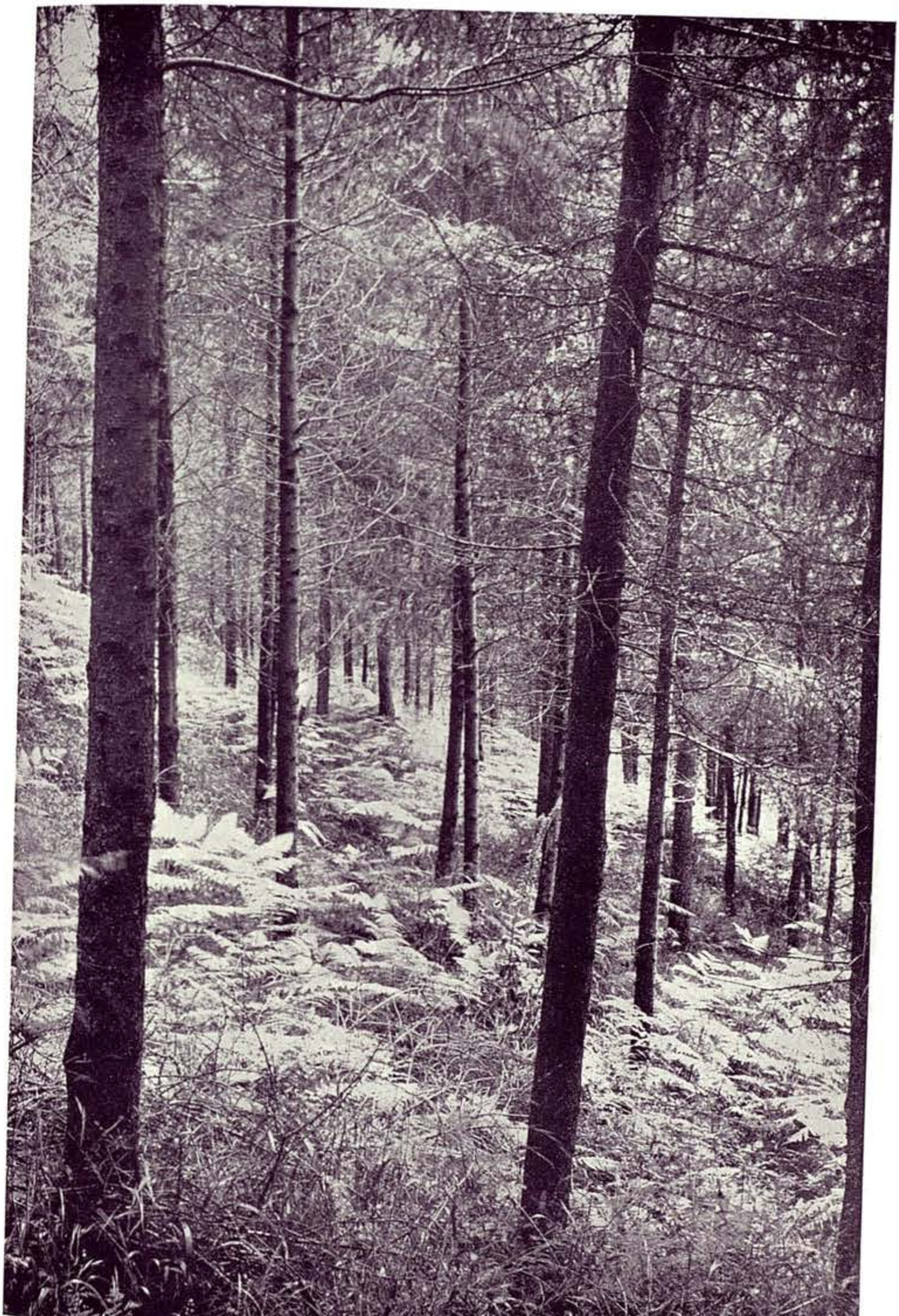


PLATE 3. Edwards: Three Races of European Larch: Darnaway Estate provenance, Moray, Scotland. Stems mostly straight, good growth.

PLATE 4. Edwards: Three Races of European Larch: Münsterthal provenance, Switzerland. a typical Alpine one. Note the upstanding branchlets and stiff needles. (Colour deep green).

PLATE 5. Edwards: Three Races of European Larch: Typical Sudeten provenance. Note the pendulous branchlets and needles. (Colour: pale green).

Table 24

Extra Cost in Man-Hours per Ton of Fresh-Stripped Bark of Sitka spruce

B.H.Q.G.O.B.* in inches	Harwood Forest	Mortimer Forest	Hafod Fawr "A"	Kershope Forest	Greskine Forest
3·0	31	—	—	—	—
3·1	27	19	—	—	—
3·2	23	15	—	—	—
3·3	19	12	—	—	—
4·0	17	9	16	21	—
4·1	15	7	14	19	22
4·2	13	5	12	17	20
4·3	—	4	10	15	18
5·0	—	3	9	14	17
5·1	—	2	8	13	16
5·2	—	1	7	12	15
5·3	—	—	6	11	14
6·0	—	—	5	10	13
6·1	—	—	5	—	13
6·2	—	—	4	—	12
6·3	—	—	4	—	—
7·0	—	—	3	—	—

Note: * Breast-Height Quarter-Girth Over Bark.

Yields of Hardwood Coppice 562.4

A survey has been designed to assess the yield of various common hardwood species grown as coppice on a 20 to 30-year rotation, with particular reference to the possible outturn of hardwood pulpwood.

The investigation was still in its preliminary stages at the end of the year under report.

Methods of Determining Moisture Content of Fresh Felled Sitka Spruce 847

Comparisons were made of the various methods of obtaining samples for determining the moisture content of fresh-felled Sitka spruce. It was found that the highest figure for the moisture content of this species was given by cross-sectional discs, 4 inches thick. A slightly lower figure was given by ½-inch-thick discs, and by sectors cut from one-inch discs, whilst increment cores using a Pressler borer gave the lowest figure. The experiment was part of a general study into the determination of the moisture content of round timber. A report on the methods used and results is given by Howell and Kemp on page 156.

Seasoning in the Forest 847.1

Seasoning experiments at Benmore and Gwydyr forests, were referred to in the *Research Report* for 1956; the Benmore experiment ended during that year and the results were discussed in that *Report*.

The experiment at Gwydyr ended this year. As at Benmore, poles of 3, 4 and 5-inch breast-height quarter-girth had been felled at quarterly intervals since the winter of 1952–53, until the end of 1955, and were left lying on brash on the forest floor until the spring of 1957. Half the poles had been peeled immediately after felling and the other half had been left unpeeled. The results relating to rates of seasoning, compressive strength, incidence of fungal attack, and degrade of timber do not show any marked difference from the results at Benmore. Peeling and spring-felling favourably influenced the rate of seasoning, but there was no clear evidence on how the treatment of the poles affected the strength in compression of the test pieces or the incidence of fungal attack. A full report is being prepared.

LIBRARY AND PHOTOGRAPHIC COLLECTION

By G. D. KITCHINGMAN

Library

945.14

The number of books in the library on the 31st March, 1958, was 3,032, an increase of 181 during the year. Loans of books and periodicals numbered 821. Borrowing from outside libraries increased from 212 to 285. Forty-nine volumes of periodicals were bound, bringing the total to 1,286.

Catalogue

A revised Library Catalogue of Books and Periodicals was published during the year.

Information Files

This section of the library shows a steady increase, and is now a very valuable collection, carefully indexed and cross-referenced in the library card catalogues, of typescript reports, reprints, translations and miscellaneous material generally. This section could now justifiably be called the "Archive Section."

Documentation

The number of cards in the indices (card catalogues) is now about 80,000, equivalent to about 27,000 references. With the arrival of a trained forest officer, progress in clearing off the large backlog, as far as reading and codifying goes, has been faster.

Lists of references to literature on special subjects were supplied to enquirers.

Bibliography of British Forest Literature

Progress continues in this special task. The references selected now number about 8,700.

Translation Section

Translations from Swedish, Danish, Norwegian, French and German, and one each from Russian and Czechoslovakian, have been undertaken.

Important translations completed are noted in the Library Quarterly. These now total 89, all of which are available under the Commonwealth Translation Exchange Scheme.

The dictionary of uncommon foreign technical terms, being built up on cards, continues to be used and extended. There are over 4,000 dictionary cards, covering 12 languages.

A.S.L.I.B.

Close contact was maintained with the Association of Special Libraries and Information Bureaux, of which the Library is a member.

Collection of Photographs

The demand for slides to illustrate lectures has once again increased. The large number of 8,640 slides loaned during the year was the highest yet. Figures for the past six years show:

For 1952–53 ..	652 slides loaned.
For 1953–54 ..	1,216 slides loaned.
For 1954–55 ..	5,081 slides loaned.
For 1955–56 ..	5,458 slides loaned.
For 1956–57	7,740 slides loaned.
For 1957–58	8,640 slides loaned.

The number of colour slides in the collection increased from 3,569 to 4,575.

Nine hundred and ninety-five photographs were loaned for various exhibitions, agricultural shows, etc.

Film distribution amounted to 166 films loaned during the year compared with 164 last year and 104 in 1955–56.

It was reported last year that much of the indexing of photographs and slides under the Oxford system of Decimal classification for Forestry had remained undone. Extra work has since been put in, and this backlog having been almost cleared, the indexing is nearly up to date.

Work on the Squirrel and Squirrel Control film has continued during the year and it is hoped to have the film ready for distribution early in 1959.

PART II

Research undertaken for the Forestry Commission by Workers attached to Universities and other Institutions

---

RESEARCHES ON MYCORRHIZA

By Dr. IDA LEVISOHN

Bedford College, University of London

181.351

Effects of Certain Microbiological Interactions on the Growth of Birch Seedlings

During the course of mycorrhizal researches conducted at Bedford College, inoculation experiments have demonstrated that the introduction of mycelia, known to be mycorrhiza-formers, frequently fails to influence the development of tree seedlings. A fairly comprehensive record is available to show that indifferent results were obtained in not less than about 40 per cent of the inoculation experiments carried out in the field and in pot-cultures. Among the remaining trials, practically all exhibited pronounced or very pronounced stimulation of young trees, species of both conifers and hardwoods, following the introduction of selected mycorrhizal mycelia.

In one single case only was inoculation found to be harmful to the experimental plants: introduction of the fungus described as *Boletus scaber* produced adverse effects on growth and vigour of birch seedlings which were grown in a certain soil from the Yorkshire moors (cf. *Rep. For. Res.* 1956, 1957). At the time, no satisfactory theory was put forward to explain the effect produced by *B. scaber* in the soil from Yorkshire.

This year (1958), early maturing was recorded for the plants in Yorkshire soil which had received mycelium of *B. scaber*. In this fourth year from sowing, the inoculated birch cultures showed flowering, while the uninoculated cultures were producing vegetative growth only. The performance of the young trees in the experiments with Yorkshire soil was particularly puzzling in view of the fact that, in other soils under investigation, the inoculated fungus, which is known as "Birkenpilz", has been observed to exercise a remarkable stimulation of birch seedlings. Beneficial effects from its introduction had also been recorded for birch cultures in the *sterilised* soil from Yorkshire.

Detailed root examination and pure culture work have now revealed that the depression in growth and vigour of the seedlings, following the introduction of *B. scaber* into the untreated soil, might be ascribed to the following microbiological interactions:

(*a*) It has been observed that, in the Yorkshire soil under observation, a root-fungus harmful to the development of young birch is active. The presence of a deleterious factor in this soil was first indicated by the performance of birch seedlings growing in pot-cultures with soil from the Wareham area to which a small inoculum of the Yorkshire soil had been added. This inoculation affected size and colour of the leaves adversely and induced early maturing. Sterilized inocula did not produce harmful effects on the young trees.

The mycelium responsible for the damage to the seedlings is now available in pure culture. It resembles in many respects a fungus described by Melin and named by him *Mycelium radicis atrovirens* β (mycelium sterile). So far, this pseudomycorrhizal fungus has not been recorded for English soils, but there is no reason to assume that the particular mycelium in question, or similar parasitic mycelia, are rare in soils of this country. Very few studies of root-fungi of the kind discussed above have been carried out, and it should be emphasized that only pure culture reactions and chemical tests are a safe guide for their identification.

(*b*) Inoculation of *B. scaber* from pure culture into the untreated soil from Yorkshire was observed to be followed by increase in attacks of the pseudo-mycorrhizal fungus. This fact seems very remarkable since *B. scaber* had long been recorded to occur abundantly in the Yorkshire area, where it was believed to be one of the main mycorrhiza-formers for birch. However, it has now been established that the sporophores at Yorkshire described as *B. scaber* belong to at least two distinct forms of this species. The Yorkshire forms of *B. scaber* are different from the form employed in the inoculation experiments discussed above. The difference in behaviour of the various forms shows very clearly in chemical and biochemical tests and is, at present, being analysed as regards their effect on seedling growth. (Origin of the form used in all previous inoculations is Sugar Hill, Wareham Heath. In the particular soils from Wareham (Morden Park and Decoy), in which inoculation resulted in stimulation of the young plants, *B. scaber* was originally absent.)

(*c*) It has been recorded earlier (*Rep. For. Res.* 1955) that the form of *B. scaber* used as inoculum shows a very vigorous rhizosphere activity accompanied by delay of mycorrhiza-formation in the experimental seedlings. Through this prevention of an early onset of mycorrhizal infection, the "unprotected" root systems seem to be exposed, at least for some time, to attacks by the pseudo-mycorrhizal fungus *M.r.atrovirens* B, present in the Yorkshire soil. In soils, however, where this kind or similar kinds of parasites are absent, e.g. sterilized Yorkshire soil and soils from the Wareham Heath, the rhizosphere activity of *B. scaber* does not create a "dangerous situation" and has a stimulating influence on growth.

The effects of the described microbiological interactions on the development of birch seedlings can be summarised as follows:

(1) Wareham soil untreated, inoc. *B. scaber*—beneficial effect.

(2) Yorkshire soil untreated, inoc. *B. scaber*—harmful effect.

(3) Yorkshire soil sterilized, inoc. *B. scaber*—beneficial effect.

(4) Wareham soil untreated, inoculated untreated Yorkshire soil—harmful effect.

(5) Wareham soil untreated, inoculated sterilized Yorkshire soil—no effect.

Further investigations concerned with an analysis of microbiological interactions involved in effects of mycorrhizal inoculations on birch and other tree species, are in progress.

In connection with the study of microbiological inter-relationships in various types of soil, in particular those from certain nurseries, laboratory work has recently concentrated on chemical methods for identifying ecological groups of soil fungi. Methods are being developed to facilitate the differentiation between, for instance, obligate and facultative mycorrhiza-formers, virulent and less virulent pseudomycorrhizal fungi, "trivial" mycelia, etc. In the course of these studies, trypton, tryptophan, and other selected media have already proved of considerable value in classifying sterile fungi of interest, isolated from root associations and from certain "difficult" soils.

STUDIES IN SOIL MYCOLOGY

By Dr. C. G. DOBBS and Dr. JOAN BYWATER

Forest Botany Section, University College of North Wales, Bangor

Mycostasis in Soils 181.351

Work has been developed along the lines proposed in the *Report on Forest Research* for 1957, in respect of assay, by spore germination counts, of the inhibition of fungal growth; a comparison of the inhibition in several different soils and soil levels throughout the year, its effect on the mycelial growth of basidiomycetes, and some factors which influence it.

Assay and Comparison of Inhibition Levels throughout the Year

The assay method finally adopted was a variant of Dr. W. H. Hinson's "open fold" method for detecting inhibition (see 1957 *Research Report*) in which the moistened soil is packed into 25 ml. cylindrical "Oxoid" caps and covered with the prepared cellulose film bearing the spores of the test fungus (*Mucor ramannianus*). The whole is incubated 48 hours at 27°C. in a moist container, the margins of the film extending beyond the soil contact area being used as controls.

Control materials which gave an equal germination to that on the "margins" were pharmaceutical kaolin and, after cleaning with chromic acid, a Barton sand from a deep level in Denny sand pit, New Forest. The percentage of spores not germinating on the soil contact area, as estimated by spore counts on a grid in randomly chosen fields, was taken as a measure of the degree of inhibition; the controls being found to maintain a fairly constant level of about 95 per cent germination. Where the growth of the germ tubes exceeded that on the margins the degree of stimulation was assessed qualitatively by eye.

These assays were carried out at approximately monthly intervals on four forest soils and on samples taken at three levels at each site, viz. surface litter at 0 to 1 inch, dark amorphous humus at 1 to 2 inches, and mineral soil at 6 to 10 inches depth. The four sites were under mature beech-oak mixture, and under mature Scots pine near the Menai Straits at about 50 feet above sea level, and under mature beech-oak mixture and under 30-year-old Norway and Sitka spruce, at about 500 feet above sea level. Surface soils from two garden sites were also assayed throughout the year and a number of other soils at occasional intervals. A parallel series of germination tests was carried on for most of the year in which the soils were moistened with glucose solutions at several concentrations. Both series, i.e. with distilled water and with glucose solution, were also duplicated with the "closed fold", in which the cellulose film is enclosed between lumps of soil, since this was thought to simulate conditions within the soil more closely than the "open" film test. As might be expected, the glucose solutions in general gave higher germination counts, and the "closed folds" much lower ones, than did the distilled water "open" series; but taken as a whole the same main seasonal tendencies were shown by all types of test, although there were several apparently anomalous results with individual soils. The "closed fold" tests have now been discontinued as the additional information did not seem commensurate with the labour involved.

Seasonal Variation

The results of the distilled water assays are summarised in Fig. 2, from which it can be seen that there is a strong seasonal variation in germination in most of the soils tested. There was in fact some seasonal variation in all of them. In each soil, inhibition was complete from July to September, 1957, but decreased during the winter, reaching a minimum in December and January, 1958, after which, as in the spring of 1957, it has been increasing again towards the high level of the summer months. During the winter months there has been a wide "scatter" of germination levels among the different forest soils, some even inducing mycelial growth and sporing of the test fungus when incubated, although the average germination percentage for all twelve samples remained at all times well below the controls. It was noticeable that all the soils which stimulated growth and sporing during the winter were from the low altitude locality near the Menai Straits.

Since the pronounced seasonal variation suggests a temperature effect, a series of preliminary tests were set up in which the soil samples, before assay at the usual incubation temperature of 27°C. for 48 hours, were kept for ten days at a range of temperatures from 27°C. downwards to -9°C. The results are at present difficult to interpret. All four samples tested, from mineral and humus layers under pine and under beech-oak mixture, showed total inhibition at all temperatures above freezing, but stimulation of growth after being frozen. In contrast, the two surface litter samples, and several marine sands from Newborough Warren, did not present any consistent picture. The sand showed no change from total inhibition after freezing. It is clear that the temperature effect requires further study.

Inhibition in a Range of Soils

Fig. 3 shows the average germination for all three soil layers at the four forest sites mentioned above, during the period May, 1957 to March, 1958. It can be seen that the inhibition did not fall off so far during the winter at the higher locality (Marian y Winllan) as at the lower (Church Island); or under the beech-oak mixtures as under the conifers. So far as the different soil-layers were concerned, the site difference was particularly marked in the mineral layers in which, at Marian y Winllan, germination never exceeded 15 per cent, while at Church Island inhibition disappeared completely in mid-winter. It was noticeable

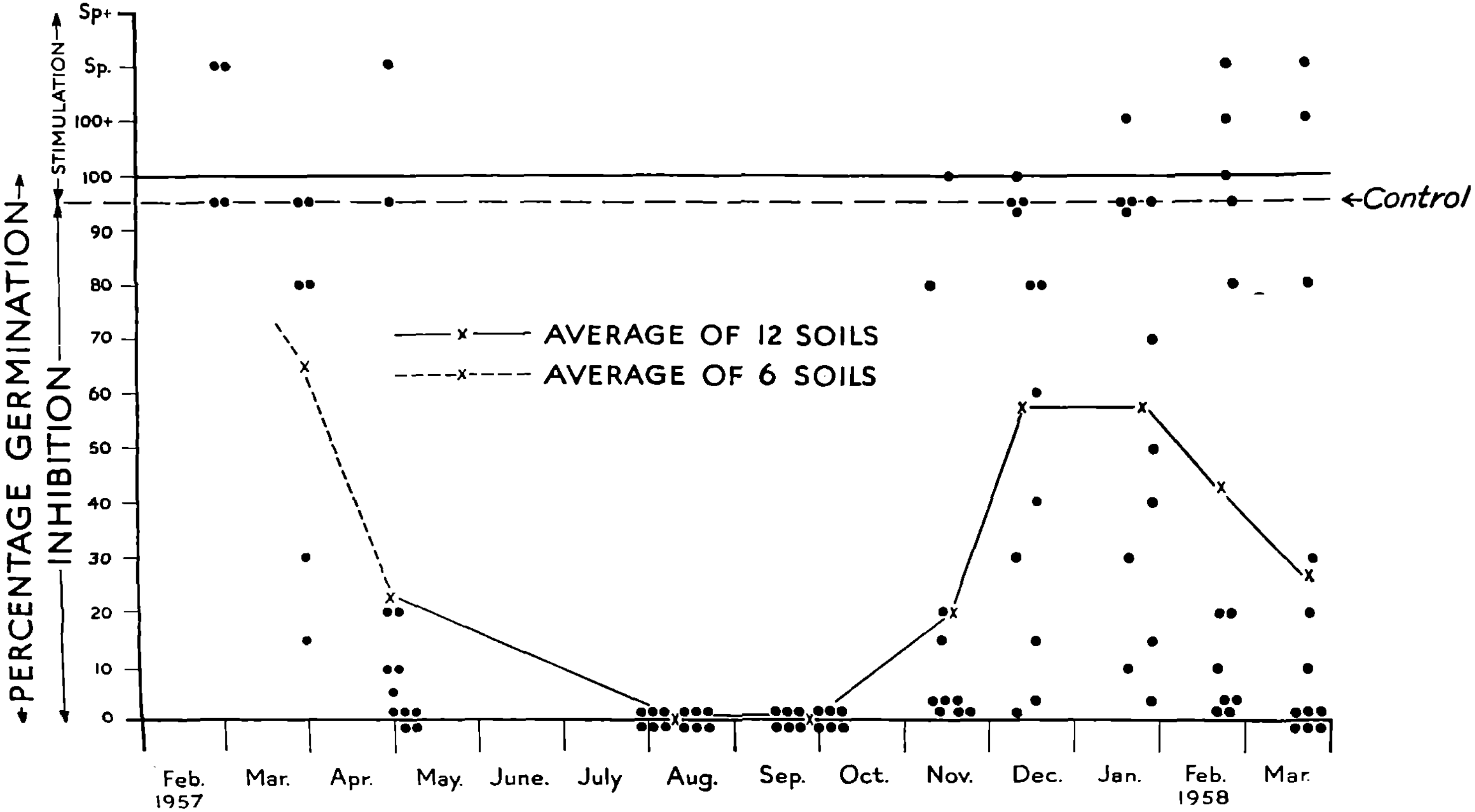


FIG. 2. Germination assay points for *Mucor ramannianus* on twelve forest soils, taken from four sites at three levels, from May, 1957. Points occupying the same position are shown in contact. The values above 100 per cent. are arbitrary estimates of stimulated growth, thus: 100+ = germ tubes united into a network; sp. = mycelium sporing moderately; sp. + = mycelicum sporing abundantly.

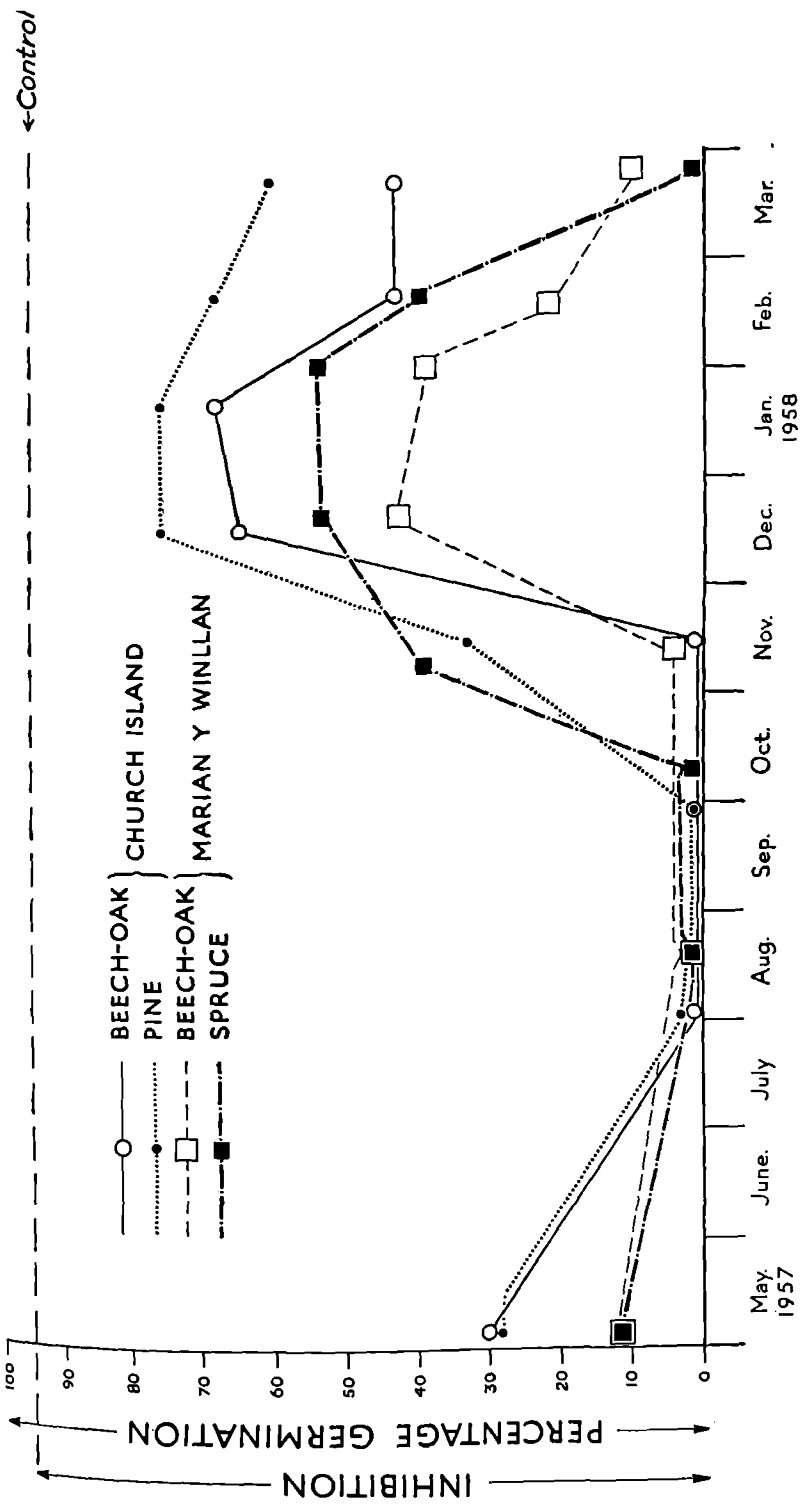


FIG. 3. Average germination (*Mucor ramannianus*) on soils from four forest sites sampled at three levels.

also that, on three of the humus layers, germination and growth reached its maximum in November or December, but on all four surface litters the maximum was reached after the New Year. The impression given is that the three soil layers investigated behave independently as regards level of inhibition.

A collection of about forty soil samples from various sites in North Wales and the south of England was assayed for germination mainly during the high-inhibition summer period. Every sample showed total inhibition with distilled water, but a range of glucose solutions brought differences to light. Generally, the addition of increasing concentrations of glucose resulted in germination and growth of the test fungus up to or beyond the control level, but in some soils the inhibition was quite unaffected by glucose solution up to 5 or even 10 per cent. In others germination occurred, but never reached the control level. Broadly, it is possible at this stage to distinguish two categories of soils: those in which the addition of glucose results in appreciable germination and growth of the test fungus, and those in which it does not.

The first category comprises most of the soils tested, including forest soils under both hardwoods and conifers with pH 4 to 5, some under grass turf and acid heath, including several samples from Wareham Heath and Sugar Hill nursery, a garden soil (pH 5·5) a Barton sand subsoil from Denny sandpit, New Forest, and sand (pH 7·4) from beneath grass turf on a fixed dune planted with Corsican pine on Newborough Warren, Anglesey. The second category comprises chalk subsoil (pH 8·5) and dark humus (pH 7·3) from chalk rendzina under beech, both from Whiteleaf Hill, Chilterns; surface and deeper samples from the Newborough Warren sand dunes, both creeping willow and marram grass zones, also a sample of dune sand from Lligwy Bay on the opposite side of Anglesey, a garden soil from a shrubby border (pH 7·1), which may have been limed as it effervesced with acid, and a sample of the notorious "toxic" surface soil (pH 4·0) from Gore Heath, near Wareham, studied by Neilson Jones and others. This last, however, gave 11 per cent germination when mixed with 5 per cent glucose solution. A second sample (pH 4·3), taken at about 8 inches depth at this point, gave 20 per cent germination with only 0·1 per cent glucose. A surface sample from burnt heath not far away gave 59 per cent germination with 0·1 per cent glucose.

The Newborough sands, which contain sea shell fragments rendering them highly calcareous (pH 7·7 to 8·3) exerted a complete inhibition on *Mucor ramannianus* under all conditions, summer and winter, after washing, freezing, autoclaving, with and without added glucose. The chalk subsoil also continued to inhibit after autoclaving, whereas most soils lose all inhibiting power and stimulate growth and sporulation. It is evident that there is in these highly calcareous soils an inhibiting factor which is non-biological, and of a different character from that which is exhibited by most normal soils and also by the Gore Heath sample with its low pH (4·0).

That pH itself is not the determining factor was demonstrated by a series of germination tests with *Mucor ramannianus* on water agar, and on beech-oak humus soil, adjusted to a range of pH values by the addition of N/10 HCl or NaOH. In both series germination was normal at all pH values between 3 and 8. Beyond these it fell off and became abnormal, being suppressed altogether at extreme values. Pure calcium carbonate also completely suppressed germination, but the addition of this to soil up to a third of its volume, raising the pH to 8·0, did not reduce it.

Inhibition of Growth in Basidiomycetes

In the 1957 *Research Report* mention was made of some inhibitory effect of soil upon the growth of *Polystictus versicolor*, and of the inconclusive results of preliminary work with macerated mycelia of other basidiomycetes. The method used with *Polystictus* had been to place moist cakes of untreated and of autoclaved soil upon a cellulose film lying upon water agar inoculated with the test fungus. The untreated soil suppressed mycelial growth, which the autoclaved soil strongly stimulated. A variant of this, in which water agar discs bearing standard 2 mm. inocula from malt agar cultures are placed upon the film, which is pressed upon the moist soil in a petri dish, has now given definite results with 11 basidiomycetes and one wood-rotting ascomycete (*Xylaria hypoxylon*). Table 25 shows the percentage reduction in diameter growth of these 12 fungi, when tested in this way upon 12 different forest soil samples and two of garden soils. The controls were similar inoculated agar discs having glass coverslips inserted between them and the cellulose film. These showed the same high germination and growth rate as controls, in which kaolin or water agar were substituted for the soils. The over-all average reduction in growth for the 14 soils tested was 84 per cent, varying for different fungi from 51 per cent for *Coniophora cerebella* to 98 for *Lentinus lepideus*. *Polyporus schweinitzii*, *Fomes annosus* and *Armillaria mellea* also showed over 90 per cent reduction in growth.

Molin (1957) in Sweden used a similar method in which he demonstrated inhibition of growth by soil in *Fomes annosus*, *Peniophora gigantea*, *Stereum sanguinolentum* and *Lentinus lepideus*. He used, however, 1 per cent malt agar discs, and sterilised soil as his control. Jackson (1958) also used a very similar method in which filter paper was used instead of cellulose film. With this he has demonstrated widespread mycostasis in Nigerian soils. The method, when tested at Bangor, resulted in the isolation of several sterile mycelia, not affected by the inhibition, which grew up into the agar. Attention should also be drawn to the work of Park (1956) who has isolated from soil a strain of *Bacillus macerans* capable, when inoculated into sterile soil, of exercising a mycostatic and indeed a toxic and lytic effect upon fungal spores and hyphae; also that of Stevenson (1956) who has isolated actinomycetes capable of exerting similar effects.

Further development of the Work

It is evident that the regular assays must be continued for at least a second year before it could be assumed that the strong seasonal variation which has occurred in 1957–58 is a normal annual occurrence. Further study is needed of the temperature relation and especially the relationship with freezing; of the characters which distinguish the inhibitory factor in strongly calcareous soils from that in normal soils; and of the occurrence of non-inhibited mycelia in soils; but the main problem is to distinguish the effects of variations in the mycostatic factor from those of contra-inhibitory nutrients in the soil. During the past year exploratory tests designed to isolate the inhibitor have raised problems of technique mainly concerned with bacterial infection which have not yet been solved.

REFERENCES

JACKSON, R. M. (1958). *J. gen. Microbiol.* 18, 248–258.
MOLIN, N. (1957). *Medd. f. Stat. skogsforskningsinst.*, 47 (3) 1–36, Stockholm.
PARK, D. (1956). *Trans. Brit. mycol. Soc.*, 39, 293–259.
STEVENSON, I. L. (1956). *J. gen. Microbiol.*, 15, 372–380.

Table 25

Percentage Reduction in Diameter Growth of Twelve Fungi on Twelve Different Soils

Fungus	Church Island						Marian y Winllan						Av. forest soils	Garden soils		Av. all soils
	Beech-Oak			Pine			Beech-Oak			Spruce				pH 5·5	pH 7·1	
	Litter	Humus	Mineral	Litter	Humus	Mineral	Litter	Humus	Mineral	Litter	Humus	Mineral				
Coniophora cerebella	100	100	33	0	0	33	100	94	67	0	11	33	48	71	78	51
Mycelium radicis atrovirens ..	44	60	63	50	25	25	71	71	71	71	29	71	54	71	93	58
Poria vaillantii	100	88	88	63	82	82	100	75	67	80	85	97	84	71	25	79
Polystictus versicolor	50	63	83	57	83	98	50	83	79	89	100	92	77	100	95	80
Xylaria hypoxylon	80	80	88	60	82	83	45	100	95	80	100	100	83	100	100	85
Hydnum coralloides	100	75	80	100	100	75	100	100	94	95	96	100	93	75	50	89
Merulius lacrymans	100	100	100	100	100	50	100	67	93	100	67	93	89	73	100	89
Collybia velutipes	33	54	100	100	100	100	100	100	100	100	100	100	91	100	93	91
Armillaria mellea	100	77	88	100	88	88	100	100	100	89	80	100	93	100	100	94
Polyporus schweinitzii.. ..	100	100	100	100	100	100	100	100	100	100	100	100	100	100	25	95
Fomes annosus	86	100	100	100	100	86	100	100	100	100	100	100	98	81	100	97
Lentinus lepideus	100	100	100	88	100	100	80	100	100	100	100	100	97	100	100	98
Average (12 fungi)	83	83	85	77	80	77	87	91	89	84	81	91	84	87	80	84

EFFECTS OF TREE GROWTH ON THE SOIL

By Dr. T. W. WRIGHT
The Macaulay Institute for Soil Research, Aberdeen

Tree Growth on Sand Dunes 181.343:114.3

At Culbin Forest, Morayshire, observation of the effects of inorganic manures on the growth of young Corsican Pine on sand dunes has continued. Two separate experiments are in progress, one with ground mineral phosphate applied in 1954, and the other with a factorial combination of nitrogen, potassium, and magnesium fertilisers applied in 1956.

The slight improvement in height growth due to phosphate, which became apparent in 1956, was maintained, although, as in the previous year, the increase was not reflected in the nutrient content of the needles. In the factorial experiment, the nitrogen treatment (5 cwt. sulphate of ammonia per acre) increased height growth in the second season after application by about 33 per cent, neither the potassium nor the magnesium having any effect. Foliage analysis again showed an increase in the nitrogen and potassium levels in the needles due to application of these elements, but no response to magnesium.

Since measurements began in 1953, annual height growth has been found to be closely correlated with the combined May and June rainfall in the same year, satisfactory growth requiring at least four inches of rain in this early part of the growing season.

Tree Growth on Deep Peat

At the Lon Mor, Inchnacardoch Forest, further attention has been given to the drying effect of trees on the peat. A laboratory study of the pF-moisture content relationship in peat from this area, using a pressure membrane apparatus, has shown that even where moisture depletion is most apparent, i.e. under the most vigorous trees growing on the shallower peat less than two feet deep, moisture contents measured in the field are still above the wilting point, but suggests that on large areas of shallow peat, where roots are unable to penetrate the underlying moraine due to compaction and poor aeration, moisture shortage could limit growth. Analysis of foilage from the manuring trials on lodgepole pine and Sitka spruce (Experiments 128 and 74), in which nitrogen, potassium, and magnesium fertilisers were applied in April, 1957, showed increased uptake of nitrogen and potassium by the end of the first growing season, but, as at Culbin, no response to magnesium. All three treatments had significantly reduced height growth, probably due to the initial high concentration of soluble salts in the soil solution.

Two new trials have been laid down in Experiment 128 (lodgepole pine) to test aqueous ammonia, calcium cyanamide, and granite dust as sources of nitrogen and potassium which may act more slowly than the usual soluble salts.

Lodgepole pine and Sitka spruce planted in 1953 on deep and shallow plough ridges on deep peat at Wauchope Forest, Roxburghshire (Experiment 4) have shown much better growth on the deep ridges. Since a preliminary investigation showed that the peat from both types of ploughing had a similar total nutrient content (the larger volume of the deep ridges being offset by the lower nutrient content of the deeper peat), a study is being made of monthly fluctuations in moisture and NH_3-nitrogen within the ridges; slightly larger amounts of NH_3-nitrogen have been found in the deep ridges at the beginning of the growing season.

Nutrient Requirements of Conifers

The relationship between the major nutrient content of the foliage of Norway spruce, the levels of these nutrients in the soil, and height growth, is being studied in a number of 20-year stands on a range of sites in East Conservancy (Scotland). Needle samples collected in October, 1957 showed marked differences in phosphorus, potassium and calcium contents depending on locality, although there was no correlation with the amounts of these nutrients in the upper (A_1) horizons of the soil. Sampling is being extended to lower horizons. The nitrogen concentration of the needles showed a strong correlation with height at twenty years in Quality Classes II to IV, thus providing further evidence of a widespread nitrogen deficiency in heathland podzolic soils. A site has been chosen at Durris Forest, Kincardineshire, to test the effect of inorganic fertilisers under these conditions.

A complementary investigation of possible optimum needle nutrient levels is being made in a number of existing fertiliser experiments laid down on a wide range of soil types between 1952 and 1955, which constitute a most useful source of material for foliage analysis. Samples from these plots will also be used to assess the relative availability of phosphorus applied as ground mineral phosphate and as triple superphosphate, and the possibility of improving nitrogen nutrition by liming raw humus soils.

SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY

Rothamsted Experimental Station, Harpenden, Herts.

114.67

A pilot experiment to test a technique for the determination of the rate of disappearance of beech litter from the forest floor has proved successful. Leaves were marked with a spot of paint containing the isotope, Tantalum 182, and it was possible to recover them up to about one year after marking. Two further experiments were established during the autumn months of the present year. In the first, leaves were marked *in situ*, and in the second, marked leaves from five beech woods with different humus forms have been placed under the same conditions to find if there is any difference in rate of disappearance of leaves from different sites.

Leaf sampling indicated that rate of disappearance during the first six months was very slow indeed, but it is probable that there was a marked acceleration during the second six months. Weather conditions may play an important part, and for this reason it would be unwise to generalise at this stage.

Mr. D. S. Madge, an undergraduate student, made a short laboratory study of the length of survival of certain species of Oribatid mites in dry air, and at relative humidity levels of 25–40 per cent. Eight species associated with contrasting habitats were chosen for these experiments. In dry air the length of survival of the species studied varied greatly. At 10°C. *Nanhermannia nana* (Nic.) survived the shortest time, 50 per cent. of the population dying in less than one hour. With *Oribatella quadricornuta* (Mich.) and *Belba* species, 50 per cent of the population survived for periods of 48–60 and around 66 hours respectively. At a temperature of 20°C. these times were usually very much shorter. On the whole the results corroborated the evidence available concerning the environmental conditions of habitats favoured by these species. *N. nana* for example, is normally associated with very wet places such as sphagnum bog, and the evidence of this experiment indicates that it can only survive a short exposure to dry air. *O. quadricornuta* on the other hand is commonly associated with very dry places such as stone walls, and it is therefore not surprising that it should survive exposure to a dry atmosphere for a very much longer time. It should be remembered, however, that the relative humidity level within moss cushions on a wall may be quite frequently within the region of 70–80 per cent. The results for *Belba* are somewhat anomalous as they are usually considered to be mesophyllous mites, and are found in leaf litter. Size of species and behavioural pattern appeared to have a marked effect on length of survival, and these may explain why the large *Belba* species survived for an unusually long time.

Laboratory studies of the biology of Oribatid mites have been continued, and cultures of a number of species have been maintained. It has been found that *Fuscozetes fuscipes* (Koch) feeds very readily on insect larvae. This is a rather surprising observation as Oribatid mites are generally considered to be detrital or fungal feeders. In collaboration with Mr. C. C. Doncaster of the Nematology Department, Rothamsted Experimental Station, investigations of possible predators of nematodes and nematode cysts have been continued.

PHYSIOLOGY OF FLOWERING IN FOREST TREES

By P. F. WAREING and K. A. LONGMAN
Department of Botany, University of Manchester

181.521

The main scope of this project was outlined in the *Annual Research Report* for 1957. Several of the experiments set up in earlier years have now yielded results.

Effect of Gravity on Flowering and Growth

The experiments set up to determine the effect of the position of the branch in relation to gravity, in Japanese larch, have given highly interesting results. Branches were trained into horizontal and downwardly-directed positions, an equivalent branch in each "whorl" being left in its naturally upwardly-directed position. The treatments were applied during April, 1958, to 2 to 5-year-old branches on 10 to 12-year-old seedling trees which had not, up to that time, borne an appreciable number of flowers. In the spring of 1958 it was observed that out of 12 treated trees, 10 showed more flowering in horizontal and particularly downwardly-directed treatments than in the controls, the difference being very marked in eight trees (Table 26).

Table 26

Effect of Gravity on Flowering in Japanese Larch

	Branch fixed in existing position	Control branch (unfixed)	Branch fixed in horizontal position	Branch fixed in downwardly-directed position
Total number of flower buds	21	90	647	1,079
Number of branches involved	11	16	13	12
Average number of flower buds per branch	2	5·5	50	90

As many as 200 flowers, mainly male but including some female, had been induced on some branches, compared with three or four flowers on the untreated branches.

The flowering of young Japanese larch is thus markedly influenced by the position of the branches in relation to gravity; the greater the branch angle (measured from vertically upwards) the heavier the flowering. Moreover, the trees have been brought into flowering at an age when they would normally bear few or no flowers. In addition to inducing flowering, the horizontal and downwardly-directed training in this experiment markedly reduced extension-growth during 1957. Similar marked reduction in growth was produced in birch by pulling down individual branches.

Effects of Photoperiodic Treatment on Growth and Flowering

Experiments are in progress to determine the effect of daylength conditions on flower-initiation in grafted trees of various species, including Scots pine, Japanese larch, birch and beech. Preliminary observations suggest that flower-initiation in birch grafts is dependent on long-day conditions.

Experimental control of daylength conditions is also being used to build up the size of seedling and grafted trees as rapidly as possible. By continuous exposure to long-day conditions in a greenhouse, it has been possible to grow seedling birch to a height of 9 feet in 12 months from sowing. Four out of 14 such seedlings produced male catkins when only 13 months old. It thus seems evident that photoperiodic treatment offers a technique for reducing the duration of the juvenile phase in birch, and this possibility is being further investigated with other species.

Photoperiodic treatment is also proving valuable in prolonging the duration of the annual growth cycle in grafted trees, so that they can be brought more rapidly to a size favourable for flowering.

Some Further Techniques for Inducing Flowering

It has been observed that where branches of birch and beech have been accidently broken, but have remained alive, there is often a great stimulation of flowering. The effect of deliberate partial breaking of branches is being investigated, as a possible technique for inducing early flowering. The physiological effect of breaking is probably different from that produced by girdling.

The primary effect of the latter treatment is no doubt to interfere with the transport of organic material in the phloem, whereas breaking the branch will also effect the movement of water and the transport of mineral nutrients in the xylem sap.

The effect of downward training in conjunction with breaking and girdling is also being investigated.

REFERENCES

LONGMAN, K. A. and WAREING, P. F. (1958). The effect of gravity on flowering and shoot growth in Japanese larch (*Larix leptolepis*, Murray). *Nature*, 182, 380, 1958.

WAREING, P. F. and NASR, T. (1958). Effects of gravity on growth, apical dominance and flowering in fruit trees. *Nature*, 182, 379, 1958.

RESEARCH ON KEITHIA DISEASE DIDYMASCELLA THUJINA

By R. G. PAWSEY

Botany Department, University of Nottingham

The completion of two constant temperature rooms in the Botany Department, in the spring of 1957 enabled experiments to be carried out on the development of *Keithia* infection under partially controlled conditions. The experimental temperatures used were 5°C., 13°C. and 20°C. One constant temperature room was maintained permanently at 5°C., and the other at 20°C. (The rooms were used by other workers which prevented the alteration of these two temperatures.) A large water-cooled incubator in the 5°C. constant temperature room provided the intermediate temperature of 13°C. by using the outside temperature in the cold room as a source of cooling. Experimental plants at all three temperatures were illuminated artifically by Sieray and fluorescent lamps.

In inoculation experiments previously carried out in open laboratory conditions, incubation periods varying from four to nine weeks were recorded. In these experiments there was no attempt to control temperature and the plants were illuminated naturally. At 20°C. in the constant temperature room, incubation periods of between two and three weeks were recorded on two-year-old *Thuja* plants which had been inoculated artificially. It was found that the most reliable method of inoculation was the attachment of sprays of heavily infected *Thuja* foliage, on which large numbers of discharging apothecia were present, to the branches of healthy potted experimental plants. The plants were inoculated in this way in small batches for two or three days in bell jars.

The infection activity of the fungus was retarded at 13°C., as indicated by the six to seven weeks' incubation period recorded at this temperature. No stage of infection was observed, either superficially or in the leaf tissue, after incubation of inoculated *Thuja* plants for five months at 5°C.

The retardation of fungal growth during later stages of infection was observed. Two-year-old *Thuja* plants were incubated at 20°C. after inoculation until early stages in the development of apothecia were produced. Batches of these plants were then transferred to 13°C. and 5°C. After four weeks, the apothecia on the plants which had been retained at 20°C. were actively discharging ascospores. On the plants incubating at 13°C., development of the apothecia had continued, but the leaf epidermis was still intact over the swollen apothecia. At 5°C., no further development of the apothecia took place.

A large number of two-year-old *Thuja* plants were incubated continuously at 5°C., following inoculation in September 1957. At approximately monthly intervals, until February 1958, batches of these plants were transferred to 20°C. In each instance symptoms of infection appeared after 14 to 19 days at 20°C. At regular intervals, sections were cut of leaves of the plants incubating at 5°C. On no occasion was any stage of infection observed in the leaf tissues. It appeared that the ascospores on the leaf surface could remain viable for a period of at least five months. A technique was devised to remove ascospores present on the leaves of inoculated plants. A medium size stencil brush was modified so that it could be held in the chuck of a small electric pistol drill. The foliage of inoculated plants incubating at 5°C. was brushed with this apparatus and the plants were then transferred to 20°C. Only a small number of plants were available for these experiments, so that no statistically significant results could be obtained. Generally, however, there was a reduction in the number of leaves infected per plant as a result of brushing. It is thought that the clefts between *Thuja* leaves constitute an important site for fungal penetration. Frequently the first symptoms of infection have been observed extending from these interleaf clefts. The presence of spores in the clefts increased the difficulty of removing surface inoculum by mechanical means. Although infection was reduced after brushing, it could not be concluded that the infection which did occur was due entirely to the activity of ascospores in the inaccessible region of interleaf clefts. Although there is no support from anatomical investigation, it is possible that a very early stage of infection, produced during the period of inoculation, was present in the cells of the epidermis.

There was evidence that ascospores on the foliage surface could survive lower temperatures than 5°C. After continuous incubation for four months at 5°C., inoculated *Thuja* plants were incubated for three weeks at 0°C. On transferring the plants to 20°C. symptoms were observed after three weeks. The degree of infection was comparable with that on plants incubated at 20°C. immediately after inoculation. Inoculated *Thuja* plants were also incubated for short periods at —5°C. but the rapid change of temperature after removal of the plants from the refrigerator caused the death of the plants so treated. Inoculated plants incubated for four weeks at 27°C., under natural conditions of illumination, did not become infected when transferred to 20°C. It would appear that the above experimental results support the conclusion that ascospores on the surface of young *Thuja* plants constitute a most important source of the infection produced under natural conditions in nurseries in the spring.

A number of experiments were carried out to remove the ascospores from experimentally and naturally inoculated *Thuja* foliage, for use in further inoculations. This process is extremely difficult because of the tenacious adhesion of the ascospores, by means of their gelatinous covering, to the leaf cuticle. Large numbers of spores were removed by vigorously washing large quantities of inoculated foliage with the aid of a mechanical shaker. The spore suspension obtained was concentrated by centrifuging. Microscopical examination of the spores removed showed that many of them were damaged by the treatment. The suspension was sprayed on to healthy *Thuja* plants, which were then incubated at 20°C. No infection was produced as a result of this inoculation, although washing the spray-inoculated foliage showed that many ascospores adhered successfully to the surface.

Further experiments were carried out to confirm the overwintering function of incipient apothecia.

It was possible, with the plants infected artificially in the constant temperature rooms, to follow the development of infection from a very early stage. The actual penetration of the epidermis was not observed, but there is strong evidence that direct cuticular penetration takes place. Initially, colonisation of the mesophyll is intercellular. Haustoria, which are most commonly bifurcated and stirrup-shaped, are produced into the mesophyll cells. After the production of external symptoms, the mesophyll tissue is disrupted with the formation of a loose mycelial matrix. This is followed later by the development of the apothecia. This is the first record of the haustoria of *Didymascella thujina.* Their presence tends to confirm the obligate nature of the fungus as a parasite. Extensive experiments to obtain *Didymascella* in artificial culture have not been successful.

RELATIONSHIP BETWEEN LARCH CANKER AND TRICHOSCYPHELLA WILLKOMMII

By Dr. J. G. MANNERS

Department of Botany, Southampton University

Freezing and Inoculation Experiments 443.3

The trees of European larch locally frozen and/or inoculated with *Trichoscyphella willkommii* in 1953, 1955 and 1956, have been maintained in frost-proof cold frames. Certain of the trees inoculated in 1953, which had produced cankers which subsequently became dormant, were frozen in a refrigerator in May, 1957, and the then dormant cankers have again become active and increased in size. This indicates that recurrent frosts will cause cankers to persist in an active state, as previously suggested on other grounds (Manners, *Res. Rep.* 1957). These trees will be harvested for anatomical investigation at the end of the 1958 growing season.

Table 27

Freezing and Inoculation Experiment on Larch Canker, 1956

Number of Trees Damaged — Assessed in May, 1958

Provenance	Treatment							
	Frozen only		Frozen + canker		Frozen + spore suspension		Frozen wet + spore suspension	
	A	B	A	B	A	B	A	B
E.L. 53/423 (Scottish origin) ..	2	0	3	1	1	0	2	1
E.L. 53/606 (Polish origin) ..	2	0	2	0	5	1	6	3

The trees frozen locally in 1955, with or without subsequent inoculation, have now been refrozen in a refrigerator, and those locally frozen in 1956 will be treated similarly in the summer of 1958. Further data from the 1956 experiment, obtained in May 1958, are given in Table 27.

Six trees of each origin were subjected to each treatment. Under each treatment the number of trees with frost damage visible one year after freezing is given in column A, and the number with cankers or similar unhealed lesions two years after freezing (in May, 1958) is given in column B. Although the total number of trees is rather small, the results indicate that the trees of Scottish origin are more susceptible to the fungus than those of Polish origin. Frost damage, in the absence of the fungus, was always healed within two years, but when the frost-affected area was sprayed with a spore suspension immediately after freezing, the number of damaged trees was greater, especially in the case of the trees of Scottish provenance, and a proportion of these did not heal but developed cankers.

All the trees frozen in 1956 will be given further frost treatment in a refrigerator in 1958, in order to determine whether any of the apparently healed trees in fact bear dormant cankers. The results obtained so far indicate that the fungus is able to enter through frost cracks, and subsequently give rise to cankers.

Spore trapping

A Hirst spore trap, of a type suitable for use in plantations, has been purchased. Certain initial difficulties involved in continuous operation under these conditions are being overcome in co-operation with the manufacturers, and it is planned to have the trap in regular operation by the winter of 1958–59, with a view to determining whether spores of *T. willkommii* are present in the air in plantations in frosty weather.

STUDIES ON MERIA LARICIS, NEEDLE-CAST DISEASE OF LARCH

By P. Biggs

Botany Department, Southampton University

443.2

Work on various aspects of the problems of needle-cast has been continued and has included a more critical examination of the isolated strains of the fungus, together with an attempt to correlate the onset of the disease with specific weather conditions.

The Fungus in Culture

Growth studies have been continued using flasks in shake culture, on a machine specially constructed for the purpose. The effects of sugars, vitamins and larch needle extract have been determined. Two per cent sucrose gave better growth than either 2 per cent glucose or 2 per cent fructose, while sucrose concentrations from 5 to 20 per cent showed better growth than did the 2 per cent concentration. The growth of all strains of *Meria* is enhanced by adding the sterile extract from the needles of either European or Japanese larch to a basal medium consisting only of mineral salts and sugars. Growth in European larch extract is faster than that shown in Japanese larch extract. This could possibly account for the prior appearance of disease symptoms on European larch, when both that species and Japanese larch were inoculated simultaneously.

Strains of *Meria* are relatively stable in culture, but may change from one to another during sub-culturing or when grown under certain conditions, e.g. the "a+" strain (highly sporing) grown at 0°C. shows islands of the "a" strain (non-sporing).

Cytological examination reveals that the hyphal cells are multinucleate, as are the conidia which contain from 2 to 9 nuclei. It is probable that each conidium receives a single nucleus during spore formation and that the division of this nucleus accounts for the multinucleate condition of the mature conidium. The subsequent saltation is therefore either the result of mutation or the division of a diploid conidial nucleus.

Spore Germination and Formation

Experiments designed to give information for use in the development of a forecasting system for *Meria* show that spores can germinate under a wide range of temperature conditions, but only a small humidity range. Germination occurs at 100, 99 and 98 per cent humidity, but not at 90 per cent or below. Development of the mycelium and spore formation are retarded at 100 per cent humidity and, while mycelial growth is greatest at 99 per cent, spore numbers are highest at 98 per cent.

Inoculation Experiments

The field experiments, planned to study the spread of the pathogen amongst trees of the same and different species, were unsuccessful owing to adverse weather conditions, and are being repeated. The inoculation of detached larch shoots grown in sugar solution has been successful, and the investigation of the infection and spread of the fungus within the needle is in progress.

Analysis of Data Supplied by the Forestry Commission Nurseries

Dates of *Meria* attack, supplied by the Forestry Commission nurseries throughout the country, together with weather information extracted from Meteorological Office records, have been used in the construction of a chart of nursery infection, from which the following trends can be noticed:

(1) Infection is dependent upon a specific relationship between the temperature and the humidity.
(2) Humidity, as measured in the Stevenson screen, of over 90 per cent for at least 24 hours, or over 70 per cent for four or five consecutive days, is necessary for infection.
(3) The time lag between the occurrence of the specific humidity conditions and the first noticeable appearance of the disease depends upon the prevailing temperatures. If the temperature is below 10°C. then the critical humidity occurs three to four weeks prior to the noticeable infection date. If the temperature is above 10°C. for twelve hours per day, the critical humidity occurs two to three weeks prior to infection and, if the temperature is above 10°C., noticeable infection occurs from ten days to two weeks after the critical humidity period.

A more detailed analysis of these infection data is planned, involving the plotting of further weather data in an attempt to forecast actual *Meria* attack.

The main sections of this investigation will be completed by September, 1958, but the analysis of disease data will be continued for several years.

SHELTERBELT RESEARCH

By J. NEIL PARKER
Department of Forestry, University of Edinburgh

Introductory

266

The ultimate objective of the shelter research project is the determination of the most suitable sites, species, structures and methods for establishment and maintenance of shelterbelts, so as to ensure maximum sheltering efficiency, particularly in connection with stock-rearing and afforestation on exposed and upland hill areas.

In the first three-year period, work was directed towards an examination of the influences exerted by shelterbelts on the microclimates of adjacent areas, and it included the development of a means of studying the efficiency of shelterbelts through examination of their windfields.

As was anticipated, the beginning of the second phase of the programme in April 1956 marked a redirection of work in favour of the silviculture and management of shelterbelts; and microclimatic and instrument studies assumed a lesser importance. Work also began on the development of a technique for describing belts with a view to classification, and perhaps at a later stage, a survey of shelterbelts in Scotland.

During the second year of the new phase of investigation, work has progressed on these lines, and is reported in detail below.

Instrument Studies

As wind is the predominant factor in the exposure complex, anemometers remain the principal instruments used in microclimatic studies. There are now nine anemometers of the same pattern in the Department, and this is considered to be the maximum number which can conveniently be operated in most circumstances by the usual team of three.

Due to pressure of other work, absence through illness and the difficulty of arranging transport at short notice, the study of wind profiles of shelterbelts has lapsed during the year. However, some anemometric studies have been made in conjunction with other work. It is not intended that work on windfields of belts should cease, as there are still problems which could profitably be investigated. Some of these, together with investigations on varying topography, were mentioned in the 1957 *Research Report*

Wear of Fabrics as a Measure of Exposure

Work has continued on this project: a cheap, simple and apparently foolproof mount has been produced; a flag of standard size has been adopted; a fabric has been selected which appears suitable at least for the preliminary experiments carried out during the winter.

These have been conducted on two sites. The first was chosen for its severity and uniformity of exposure, and 20 units were used there for the final evaluation of fabrics. It has since been employed to collect information and make observations on the effect of different weather conditions on flags, and to examine the consistency of reaction of the material to exposure.

The second site covers a range of exposure, and eight batteries of three units each have been established there for two months. When evaluated, data from these experiments, coupled with observations on the sites, should make it possible to decide whether the method has practical possibilities for comparing or assessing exposure. At the moment it seems to be a promising line of study.

Silviculture and Management of Shelterbelts

Although no further systems have come under management during the year, co-operation with landowners has continued, and contacts have been made which might result in planned management of other areas being undertaken. Skeleton management plans for some of these areas have been produced for consideration by the landowners. Work on the two systems already under management is progressing, and has included experimental planting and thinning of long-neglected belts.

At the Edinburgh Centre of Rural Economy, Midlothian, experimental planting and treatment have continued. New species have been added to the stocks and planted in some of the belts. Most of these species are shrubs, or plants giving low cover or shelter, although some tree species not generally available have been used.

Survey of Shelterbelts

The description of shelterbelts was continued, some 140 belts in all being recorded, mainly in the Lothians. The method of selecting belts to be described was as before: areas on the one-inch Ordnance Survey map showing concentrations of belts were visited and a number described.

After a series of revisions a final edition of descriptive format, including the salient features of shelterbelts, was decided upon and is now in use.

The accumulation of a large number of descriptions, and a need for direct comparisons of certain features of shelterbelts during a process of classification, required a method of reference. Accordingly a punched-card index system of reference has been developed for the descriptions collected.

A number of features have been selected from those included in the descriptive format, and on these are based methods of classifying shelter-belts into general types, for which tentative management proposals can be made.

Miscellaneous

During the early summer of 1957 a visit was made to the coastal district of the county of Nairn. The particular problems there were studied and information including descriptions was collected. The Department is now in a good position to give advice or assistance should landowners in the district contemplate provision of much needed shelter or treatment of decadent belts. Such advice has been offered but no scheme has yet been adopted there.

Throughout the year attention has been given to keeping the card-index of references up-to-date; some papers have been collected and translations made. Collection of photographs of shelterbelts and subjects of shelter interest has been continued.

SOIL FAUNA RESEARCH

By D. R. Gifford
Department of Forestry, University of Edinburgh

114.67

A start was made at Ae Forest, Dumfriesshire, in evaluating the effect of establishment of a tree stand on the soil-inhabiting mites. It was found very early on that it would be impracticable to undertake determinations of all the groups found, and at the same time deal with the collections quantitatively, as they frequently contain very high populations. Therefore the present emphasis is upon the mites, which are of particular interest because of their abundance and variety in the soils under study, and also because so little is known about them.

The first part of the programme has been to compare the mites of the open moorland with those of a plantation. Two sites of comparable aspect, the same altitude and the same soil profile in all but the litter and the grass root system, were chosen: the first on unploughed open moorland at 950 feet elevation on 12 inches of peat over boulder clay, supporting a vegetation dominated by grasses, *Molinia caerulea* being the most abundant, with some bilberry; the other in 30-year-old Sitka spruce in Compt. 12, with the same altitude and profile, except that it lacks a ground flora and instead has a litter layer of Sitka spruce needles and shows a gradation to amorphous organic matter where the previous grassy vegetation existed. There appears to be a tendency for the peat to break up, or at least to be changing character under the Sitka spruce, which was established without ploughing, and apparently without other special treatment, except drainage where the peat is deeper.

Initial sampling of the two areas aimed at providing as complete a picture as possible of the fauna, for systematic purposes. Therefore no quantitative results have yet appeared in the comparison; however, there seems to be little difference in the specific composition of the two areas; planting seems to have brought about a greater vertical distribution, particularly of *Oribatid* mites; *Mesostigmatid* mites, which are possibly dependent upon *Collembola* for their food supply, seem to be more numerous in Sitka spruce litter than elsewhere, and some species found there have not as yet appeared in collections from *Molinia* grassland. The possibility that these results reflect variations in the capacity of the extraction apparatus to deal with the two differing soils cannot, however, be ignored.

But the general inference is that the fauna under Sitka spruce is derived from that of the *Molinia* moorland, and that there have been some changes in numbers and composition; these have, however, not yet been related to any environmental studies.

The current programme is a study of the aggregations which seem to occur among mites, particularly *Oribatids*, to see whether these throw light on the change in population structure produced in the plantation, and at the same time a quantitative repetition of the original comparison to evaluate such changes as may have occurred.

During the period under review the sampling apparatus mentioned in last year's report was completed, with a battery of twelve funnels, having arrangements for control of humidity and temperature above and below the sample.

PART III

Reports on Results of Individual Investigations

USE OF TRIPLE SUPERPHOSPHATE FOR FOREST MANURING

By M. V. EDWARDS

232.425.112

Ground mineral phosphate is commonly applied in making plantations on poor acid peat and upland heaths. One-and-a-half ounces per plant is the normal dose for species of pine. Phosphate is more essential for Sitka spruce and some other species than for pines, especially when the site is likely to be invaded by heather, and for these species the same rate of application is used over a wider range of sites; on the poorest, the dose may be increased to two ounces per plant. The phosphate is applied by hand, a small measureful being placed or thrown on the ground round the stem of each plant shortly after planting.

The advent of triple superphosphate suggested that considerable economies might be made on account of its much higher phosphate content, if smaller amounts gave results equivalent to normal doses of ground mineral phosphate. Reduction in the weight and bulk of fertiliser to be applied is a much more important consideration in forestry than in agriculture, because it often has to be used in remote places inaccessible to wheeled transport and even when brought in bulk as close to the plantation as is possible, it has then to be carried and applied by hand.

In June 1953 triple superphosphate was used for top-dressing a 14-year-old checked Sitka spruce plantation in Cairn Edward Forest (Bennan section, Compt. 52) in Kirkcudbrightshire. The trees were a foot or two high, and half an ounce was given to each. The results were excellent. The colour of the needles changed from yellowish to green in the first season, and subsequently the growth of the plants increased. There were no casualties.

Early trials with superphosphate and with a proprietary fertiliser containing superphosphate had sometimes resulted in serious casualties, thought at the time to be due to the presence of the superphosphate, and after 1936 superphosphate was avoided. (Zehetmayr, 1954, pages 68–69.) Later work has shown that superphosphate can be used after planting both successfully and safely (Crowther, 1951). This is only true however at normal rates of application, and in one experiment (Twiglees Forest, Dumfriesshire, Expt. 6 of 1952), applications of six ounces of superphosphate five years after planting caused heavy casualties, though equal quantities of ground mineral phosphate were harmless. In the early trials the phosphate was often placed under the turf before the trees were planted, but subsequently spreading of the phosphate on the surface of the soil around the stem of the plant became the normal method of application.

It was expected that the most important difficulty to be feared in using triple superphosphate was the chance that it might kill or damage the trees soon after application, especially in dry seasons, when because of its high solubility in the limited amount of moisture available, it might prove toxic. There was also the possibility that the non-phosphatic content of ground mineral phosphate might have some beneficial effect not given by triple superphosphate.

Ground mineral phosphate has a total phosphate (P_2O_5) content of 26 to 29 per cent by weight. In these experiments commercial mineral phosphate rated at 29 per cent was used. The phosphate content of the triple superphosphate was 47 per cent. The phosphate in ground mineral phosphate is classed as "insoluble in citric acid", whereas that in the triple superphosphate is soluble. Solubility in citric acid is not, however, an exact criterion of the availability of the phosphate to the tree, and the effective phosphate content of triple superphosphate and ground mineral phosphate are believed to lie in the ratio of about three to one. The cost of the two materials is also approximately in the same ratio.

Details of the Experiments

In 1954, experiments were commenced by J. W. L. Zehetmayr comparing half an ounce of triple superphosphate with one and a half ounces of ground mineral phosphate, each applied in the normal way, as described above. Fearing that direct application of the triple superphosphate round the stem of the trees might be harmful, it was decided to test its application with special care, and it was spread in an annular band between three and six inches away from the stem so that there should be no chance of the fertiliser coming into direct contact with the plant. In some experiments, in which the trees were planted on sloping ploughed ridges, the phosphate was applied only in a semi-circular band on the lower side of the plants to avoid any wash of phosphate directly on to their stems, or via the planting notch to their roots. In another precautionary treatment, the triple superphosphate was put into the soil in two spade notches three inches away and on each side of the plant. However, in certain experiments where the phosphate was applied some months after tree planting, it was feared that spade notches might injure the roots, and so the phosphate was dibbled into a hole about three inches away from the plant. These special methods seemed particularly desirable with triple superphosphate, because it was feared that its granular form might make it liable to roll away when deposited on a slope.

Different species were employed in the tests, and ten experiments were started, three including two species in each, so that in all there were one comparison using Scots pine, five with lodgepole pine, two with Japanese larch and five with Sitka spruce. Four to six replications of each treatment in randomised blocks were included in each experiment. The summer of 1954 was remarkably damp, and it was thought that under such conditions the possible toxic effects of triple superphosphate might not become apparent. Therefore in 1955 a further set of experiments was laid down, one on Scots pine, six on lodgepole pine, two on Japanese larch and two on Sitka spruce. Further trials on other species have since been commenced but are not reported here.

A wide variety of sites both on upland heaths and on deep acid peat was covered, from Ross-shire to Yorkshire (for details see Tables 34 and 35).

Results: 1954 Experiments (Tables 28–30)

In the first two years, survival was very good in all experiments and with all species. There were few significant differences between treatments, and the special methods of application were shown to be unnecessary.

At the end of the third season both survival and height were assessed. Comparing the survival of plants treated in the normal manner with triple superphosphate or mineral phosphate, there were no significant differences in ten out of the thirteen comparisons. In two, triple superphosphate caused significant decreases in survivals of about 12 per cent, and in one a significant increase of 2 per cent.

Considering height growth, in many experiments there were significant increases in all phosphate treatments as compared with the unfertilised controls, which had been included in cases where there had been doubt whether any form of phosphate would prove beneficial or not. But between the two forms of phosphate there were only two cases of significant difference, one in favour of triple superphosphate and one in favour of ground mineral phosphate.

Results: 1955 Experiments (Tables 31–33)

It was expected that the dry summer of 1955 would lead to many casualties with triple superphosphate, but in fact there were no significant differences between the two fertilisers, in spite of the fact that drought conditions were recorded at and after the time of application in many experiments. Survival was uniformly good in all treatments at the end of the first season, and as a result a number of experiments were not assessed in the following year. Damage by hares, deer and sheep occurred, however, in several experiments, and many plants died in the winter, probably because they had not become well established in the drought. By the second year, therefore, many experiments showed heavy casualties, but assessment did not reveal any relation between the deaths and the fertiliser treatments. The third-year assessment of survival and height similarly showed no significant differences.

Discussion

It is clear that ½ oz. triple superphosphate can safely be used in place of 1½ oz. of ground mineral phosphate, and that there will be little difference in the beneficial effects. Significant differences in the results, either in survival of the plants or their growth and health are rare, and may be in favour of either material. Records of the colour of the plants showed that in a number of cases, mineral phosphate produced plants of a slightly darker green colour, but the effects were transient and made no difference to growth. In one or two cases the better colour was given by plants treated with triple superphosphate. These effects are similar to those noted many years ago when basic slag was being compared with mineral phosphate. At that time early reports suggested that basic slag gave superior results, not only in colour but sometimes in growth, but the effects did not persist.

It is not, or course, certain that the phosphate available to the young trees is exactly the same in ½ oz. of triple superphosphate as in 1½ oz. of ground mineral phosphate under different conditions, whether of soil or climate. These experiments give no indication that either form is more suited to particular species, particular soil types or particular localities, with the exception of the first experiment at Broxa in Yorkshire, where growth of Japanese larch was better with ground mineral phosphate than with triple superphosphate. The reason remains unexplained.

The experiments show that no special method of placing the triple superphosphate is necessary, though placing it into notches on either side of the plant was actually harmful in one case (Harwood Dale, Expt. No. 44), perhaps by allowing the fertiliser to come into contact with active root tips. In view of these results, the casualties which occurred in the experiments of 25 years ago may perhaps be attributed either to the placing of the fertiliser under the turf, in the "sandwich" between the original surface and the inverted turf, through which the roots of the plant were then inserted, or alternatively to the short time-lapse between planting and fertilising. In these experiments no fertiliser was applied less than seven days after planting, and it was usually more. There being no practical advantage in applying fertiliser quickly after planting, it is not proposed to carry out fresh experiments on time-lapse.

The effect of ground mineral phosphate is known to persist for many years, and there is the possibility that the effect of triple superphosphate, which is more soluble, will be less enduring. Though there is no evidence of this as yet, these experiments will be retained and observed to check this point.

During the course of the experiments, it was found that the granular form of triple superphosphate was no disadvantage in comparison with ground mineral phosphate, provided that the latter was applied in the "normal manner" as defined above. In some cases, especially when application is paid for at piece work rates, ground mineral phosphate may be put on by throwing it from a distance. Triple superphosphate cannot be accurately put on in this way if the plant has been set on a plough ridge, for much of it may fall into the furrow bottom. It is necessary for the applier to bend his back slightly, and ensure that the fertiliser falls on the ground around and within about a foot of the stem of the plant, and not on the foliage. Equal care is however, necessary for the efficient application of ground mineral phosphate, especially when it is windy.

The Use of Triple Superphosphate in Large-Scale Afforestation

During the course of these experiments, increasing use of triple superphosphate has been made in normal practice, and where a dose of two ounces per plant of ground mineral phosphate has been in common use, it has been replaced by two-thirds of an ounce of triple superphosphate. Thus in the North Conservancy of Scotland, in 1957, over eight tons of triple superphosphate were used successfully at this rate.

Conclusions

The conclusion to be drawn from this work is that the differences between the effects of 1½ oz. of ground mineral phosphate and ½ oz. of triple superphosphate, are not significant. The ½ oz. of triple superphosphate has been shown to be equally beneficial to all the species tested, and no damage is to be expected from applications made in the normal manner.

Ground mineral phosphate may continue to be used in normal practice, but wherever the saving in bulk by using triple superphosphate is likely to be of value, this latter fertiliser may be used instead, at one-third of the rate used for ground mineral phosphate.

REFERENCES

CROWTHER, E. M., 1951. *Rep. For. Res.* 1949–50, 105.

ZEHETMAYR, J. W. L., 1954. *Experiments in Tree Planting on Peat.* Bull. For. Com. 22.

Table 28

Trials of Triple Superphosphate 1954 Experiments: Survival per cent at end of First Season

Species	Forest and Expt. No.		Unmanured control(1)	G.M.P. 1½ oz.	Triple Superphosphate ½ oz.			Level of significance	No. of days between planting and application of fertiliser
				Applied in normal manner(2)		Applied with special care(3)			
				Around base of stem		Notched 3 in. away from plant	Spread 3 to 6 in. away from plant		
Scots pine	Rosedale	6	—	100	100	100	100	No differences	2 yrs.
Lodgepole pine	Carrick	3	—	99	99	97	98	Not significant	27
	Dundonnell ..	2	—	99	82†	93	94	Significant at 1%	31
	Harwood Dale..	44	100	99	100	92†	100	Significant at 1%	100–130
	Inchnacardoch	143	—	100	100	96	99	Not significant	13
	Kielder* ..	73	97	94	91	95	94	Not significant	14–44
	Mean		—	98	94	95	97		
Japanese larch	Broxa* ..	94	—	78	70	76	82	Not significant	>90
	Rosedale* ..	7	—	100	100	100	100	No differences	>90
	Mean		—	89	85	88	91		
Sitka spruce	Broxa* ..	94	—	100	97	99	96	Not significant	>90
	Carrick ..	4	—	99	99	98	100	Not significant	40
	Glentrool ..	14	—	92	86	86	89	Not significant	7
	Kielder* ..	73	100	97	98	99	99	Not significant	14–44
	Rosedale* ..	7	—	100	100	100	100	No differences	>90
	Mean		—	98	96	96	97		
All Expts.	Grand mean		99	97	94	95	96		

Notes: (1) Only on sites where phosphate was not considered essential to good growth.
(2) " Normal Application" is to throw the phosphate around the base of the stem.
(3) Varied in detail on different sites according to method of ploughing and planting.
All the experiments were planted in 1954, except Rosedale 6, where the plants were two years old when fertilised.

* Planted in mixture.
† Highly significantly less than all other treatments.

Table 29

Trials of Triple Superphosphate, 1954 Experiments: Survival per cent at end of Third Season

Species	Forest and Expt. No.		Unmanured control(1)	G.M.P. 1½ oz.	Triple Superphosphate ½ oz.			Level of significance
				Applied in normal manner(2)		Applied with special care(3)		
				Around base of stem		Notched 3 in. away from plant	Spread 3 to 6 in. away from plant	
Scots pine ..	Rosedale ..	6	—	98†	100	100	100	Significant at 1%
Lodgepole pine	Carrick	3	—	32	22‡	38	35	Significant at 1%
	Dundonnell ..	2	—	93	80†	89	91	Significant at 5%
	Harwood Dale ..	44	100	98	97	88‡	98	Significant at 1%
	Inchnacardoch ..	143	—	96	94	94	97	Not significant
	Kielder*	73	87	84	82	81	78	Not significant
	Mean		94	81	75	78	80	
Japanese larch	Broxa*	94	—	72	62	74	77	Not significant
	Rosedale* ..	7	—	99	98	99	98	Not significant
	Mean		—	86	80	86	88	
Sitka spruce ..	Broxa*	94	—	97	91	97	91	Not significant
	Carrick	4	—	95	95	95	99	Not significant
	Glentrool ..	14	—	90	78	77	85	Not significant
	Kielder*	73	99	97	96	98	99	Not significant
	Rosedale* ..	7	—	100	99	98	99	Not significant
	Mean		—	96	92	93	95	
All Expts. ..	Grand mean		95	89	84	87	88	

Notes: (1) Only on sites where phosphate was not considered essential to good growth.
(2) "Normal Application" is to throw the phosphate around the base of the stem.
(3) Varied in detail on different sites according to the method of ploughing and planting.

* Planted in mixture.
† Significantly less than all other treatments.
‡ Highly significantly less than all other treatments.

Table 30

Trials of Triple Superphosphate, 1954 Experiments: Mean Height in feet at end of Third Season

Species	Forest and Expt. No.		Unmanured control(1)	G.M.P. 1½ oz.	Triple Superphosphate ½ oz.			Level of significance
				Applied in normal manner(2)		Applied with special care(3)		
				Around base of stem		Notched 3 in. away from plant	Spread 3 to 6 in. away from plant	
Scots pine ..	Rosedale ..	6	(2·6)	3·0	3·0	2·9	3·1	Not significant
Lodgepole pine	Carrick	3	—	—	Grazed by sheep	—	—	—
	Dundonnell ..	2	—	1·3	1·4	1·3	1·3	Not significant
	Harwood Dale ..	44	1·6†	1·8	1·7	1·7	1·8	Significant at 5%
	Inchnacardoch ..	143	—	0·9	1·0	1·2	1·1	Significant at 5%
	Kielder*	73	0·7‡	1·2	1·2	1·1	1·1	Significant at 1%
	Mean ..	..	1·64	1·30	1·32	1·32	1·32	
Japanese larch	Broxa*	94	(1·6)	2·8§	2·3	2·4	2·3	Significant at 1%
	Rosedale* ..	7	(1·9)	2·8	2·8	2·8	2·8	Not significant
	Mean ..	..	1·75	2·80	2·55	2·59	2·56	
Sitka spruce ..	Broxa*	94	(1·9)	2·5	2·3	2·4	2·3	Not significant
	Carrick	4	—	1·1	1·1	1·2	1·2	Not significant
	Glentrool ..	14	—	1·7	1·7	1·6	1·6	Not significant
	Kielder*	73	1·1‡	1·3	1·2	1·2	1·3	Significant at 1%
	Rosedale* ..	7	(2·1)	2·3	2·4	2·3	2·3	Not significant
	Mean ..	..	1·70	1·78	1·74	1·74	1·74	
All Expts. ..	Grand mean ..	..	1·69	1·90	1·84	1·84	1·85	

Notes: (1) Only on sites where phosphate was not considered essential to good growth. Figures in brackets relate to random samples from surround.
(2) "Normal Application" is to throw the phosphate around the base of the stem.
(3) Varied in detail on different sites according to the method of ploughing and planting.
All the experiments were planted in 1954 except Rosedale 6 where the plants were two years old when fertilised.

* Planted in mixture.
† Significantly less than the best treatments.
‡ Highly significantly less than the best treatments.
§ Highly significantly greater than all other treatments.

Notes on the 1954 Experiments. (Tables 28 to 30.)

Dundonnell Experiment No. 2. Lodgepole pine

Plants fertilised with triple superphosphate appeared darker green in colour and with longer shoot growth at the end of the first season than plants treated with ground mineral phosphate.

Inchnacardoch Experiment No. 143. Lodgepole pine

Although the fertilisers were applied on an "ideal" day—no wind and with damp soil—triple superphosphate caused brown tips to the needles at the end of the first season, and slightly but not significantly more deaths, but the survivors gave the best results in subsequent growth. In the second year, plants treated with triple superphosphate appeared to have longer needles, and they were significantly taller after the third year than plants treated with ground mineral phosphate.

Carrick Experiment No. 3. Lodgepole pine

No differences between treatments in the first year, but heavy losses occurred in the second season owing to drought, hares and sheep. These losses were significantly different in one treatment, but it seems doubtful if this was a direct result of the application of triple superphosphate.

Glentrool Experiment No. 14. Sitka spruce

During the first year, plants treated with triple superphosphate were of a darker green colour than the plants in the other treatments, but the effect was transient.

Kielder Experiment No. 73. Lodgepole pine

In the third winter, many plots treated with triple superphosphate showed plants with yellow or brown tipped needles. This was only seen in one plot treated with ground mineral phosphate. There were no subsequent significant differences in survival or height growth.

Rosedale Experiment No. 6. Scots pine

In the second year the plants treated with ground mineral phosphate were reported as showing a better colour than the rest, but visual assessment suggesting better growth was not confirmed by measurement.

Broxa Experiment No. 94. Japanese larch

Mineral phosphate increased height growth significantly at three years of age over all triple superphosphate treatments.

Broxa Experiment No. 94. Sitka spruce

Mineral phosphate increased height growth at three years slightly, but not significantly, more than triple superphosphate, and the needles appeared rather less "blasted" after the third season.

Harwood Dale Experiment No. 44. Lodgepole pine

Notching of triple superphosphate caused highly significantly greater losses in the first year than all other treatments, and they increased in the second year. The fertilisers were applied in July after planting in March, and to avoid damaging the roots by a spade notch, a dibble was used instead. This apparently permitted the triple superphosphate to reach the roots and kill the plants, and thus the "protective" treatment proved to be more harmful than superficial application round the plant. In the first season mineral phosphate resulted in the best colour of foliage but the effect was transitory.

Carrick Experiment No. 4. Sitka spruce
Rosedale Experiment No. 7. Japanese larch
Rosedale Experiment No. 7. Sitka spruce
Kielder Experiment No. 73. Sitka spruce
} No differences recorded.

Table 31

Trials of Triple Superphosphate, 1955 Experiments: Survival per cent at end of First Season

Species	Forest and Expt. No.		Unmanured control(1)	G.M.P. 1½ oz.	Triple Superphosphate ½ oz.			Level of significance	No. of days between planting and application of fertiliser
				Applied in normal manner(2)		Applied with special care(3)			
				Around base of stem		Notched 3 in. away from plant	Spread 3 to 6 in. away from plant		
Scots pine	Harwood Dale	46	95	98	96	96	97	Not significant	75
Lodgepole pine	Carrick ..	6	—	82	84	82	86	Not significant	75
	Glentrool ..	16	—	90	93	91	90	Not significant	74
	Inchnacardoch	145	—	Experiment closed		Eaten by game			
	Kielder* ..	75	93	90	93	85	94	Not significant	19
	Lael	16	—	91	83	78	86	Not significant	12
	Teindland ..	88	96	94	97	95	97	Not significant	<30
	Mean ..	..	94	89	90	86	91		
Japanese larch	Broxa	100	74	75	78	71	74	Not significant	>80
	Drumtochty ..	15	87	100	98	99	99	Not significant	6 months
	Mean ..	..	80	88	88	85	86		
Sitka spruce	Kielder* ..	75	95	96	91	96	96	Not significant	19
	Wauchope ..	5	92	95	98†	93	97	Sigt. at 5% level	2 years
	Mean ..	..	94	96	95	95	96		
All Expts.	Grand mean ..	..	90	91	91	89	92		

Notes: (1) Only on sites where phosphate was not considered essential to good growth.
(2) "Normal Application" is to throw the phosphate around the base of the stem.
(3) Varied in detail on different sites according to the method of ploughing and planting.

* Planted in mixture.
† Significantly greater than all but one other treatment.

Table 32

Trials of Triple Superphosphate, 1955 Experiments: Survival per cent at end of Third Season

Species	Forest and Expt. No.		Unmanured control(1)	G.M.P. 1½ oz.	Triple Superphosphate ½ oz.			Level of significance
				Applied in normal manner(2)		Applied with special care(3)		
				Around base of stem		Notched 3 in. away from plant	Spread 3 to 6 in. away from plant	
Scots pine ..	Harwood Dale ..	46	88	93	93	92	93	Not significant
Lodgepole pine	Carrick	6	—	42	56	47	57	Not significant
	Glen Trool ..	16	—	90	98	98	98	Not significant
	Kielder*	75	91	89	90	82	92	Not significant
	Lael	16	—	86	76	77	78	Not significant
	Teindland ..	88	96	93	93	96	96	Not significant
	Mean		94	80	83	80	84	
Japanese larch	Broxa	100	72	63	65	60	63	Not significant
	Drumtochty ..	15	94	98	95	98	99	Not significant
	Mean		83	80	80	79	81	
Sitka spruce ..	Kielder*	75	89	93	87	93	94	Not significant
	Wauchope ..	5	89	91	93	89	98†	Significant at 5%
	Mean		89	92	90	91	96	
All Expts. ..	Grand mean		88	84	85	83	87	

Notes: (1) Only on sites where phosphate was not considered essential to good growth.
(2) "Normal Application" is to throw the phosphate around the base of the stem.
(3) Varied in detail on different sites according to the method of ploughing and planting.

* Planted in mixture.
† Significantly greater than all other treatments.

Table 33

Trials of Triple Superphosphate, 1955 Experiments: Mean Height in Feet at end of Third Season

Species	Forest and Expt. No.		Unmanured control(1)	G.M.P. 1½ oz.	Triple Superphosphate ½ oz.			Level of significance
				Applied in normal manner(2)		Applied with special care(3)		
				Around base of stem		Notched 3 in. away from plant	Spread 3 to 6 in. away from plant	
Scots pine ..	Harwood Dale ..	46	1·0‡	1·5	1·5	1·5	1·5	Significant at 1%
Lodgepole pine	Carrick	6	—	0·7	0·7	0·7	0·7	No differences
	Glen Trool ..	15	—	1·1	1·1	1·1	1·0	Not significant
	Kielder*	75	0·9‡	1·4	1·3	1·3	1·4	Significant at 1%
	Lael	16	—	1·4	1·4	1·5	1·4	Not significant
	Teindland ..	88	0·7‡	1·0	0·9	1·0	1·0	Significant at 1%
	Mean		0·8	1·12	1·08	1·12	1·10	
Japanese larch	Broxa	100	2·3	2·6	2·5	2·6	2·6	Not significant
	Drumtochty ..	15	1·4‡	1·6	1·6	1·7	1·6	Significant at 1%
	Mean		1·8	2·1	2·0	2·2	2·1	
Sitka spruce ..	Kielder*	75	1·3‡	1·6	1·5	1·6	1·5	Significant at 1%
	Wauchope ..	5	1·8	1·7	1·7	1·6	1·8	Not significant
	Mean		1·6	1·6	1·6	1·6	1·6	
All Expts. ..	Grand mean		1·34	1·46	1·42	1·46	1·45	

Notes: (1) Only on sites where phosphate was not considered essential to good growth.
(2) "Normal Application" is to throw the phosphate around the base of the stem.
(3) Varied in detail on different sites according to the method of ploughing and planting.

* Planted in mixture.
‡ Highly significantly less than all other treatments.

Notes on the 1955 Experiments. See Tables 31 to 33.

Lael Experiment No. 16. Lodgepole pine

No significant differences, but it was noted that in the first season during the drought the notched treatment had opened out on the peat, though not on mineral soil, and caused deaths. The triple superphosphate treatments caused darker glossier green colour to the foliage than ground mineral phosphate.

Drumtochty Experiment No. 15. Japanese larch

The triple superphosphate treatment resulted in darker green foliage to the plants in the first season, and these appeared more vigorous (i.e. less spindly) at three years of age.

Carrick Experiment No. 6. Lodgepole pine

Glentrool Experiment No. 16. Lodgepole pine

No significant differences. The Carrick experiment suffered heavy losses in the second year, either by drought or exposure, or both; and the Glentrool experiment by hares, from which many plants recovered in the third year.

Wauchope Experiment No. 5. Sitka spruce

The experiment was fertilised two years after planting when it was seen to be going into check. It was re-drained by ploughing at intervals of about 50 feet between rows. At the end of the next season, triple superphosphate applied by normal methods had reduced casualties significantly in comparison with the unfertilised control and was the best treatment, though the protective methods of applying triple superphosphate and ground mineral phosphate did not give significantly inferior results.

Teindland Experiment No. 88. Lodgepole pine

Kielder Experiment No. 75. Lodgepole pine

Kielder Experiment No. 75. Sitka spruce

Broxa Experiment No. 100. Japanese larch

Harwood Dale Experiment No. 46. Scots pine

No differences between fertiliser treatments recorded, but in some cases all gave better results than the controls. In most experiments poor growth due to drought was recorded, and it was clear that even under such conditions triple superphosphate was not harmful.

Table 34

Site Details—1954 Experiments

Forest	County	Expt. No.	Species	Elevation (ft.)	Aspect	Exposure	Underlying Geology (Drift often present)	Soil	Rainfall (in.)	Vegetation before planting
Dundonnel ..	Wester Ross ..	2	Lodgepole pine	950	SW	Moderate	Irregular moraine drift on Moine schists, mainly siliceous, some micaceous.	1 to 4 ft. or more of peat over podsolized drift.	70–80	*Trichophorum caespitosum/Calluna vulgaris*, with *Erica tetralix* and *Molinia caerulea*.
Inchnacardoch	Inverness-shire	143	Lodgepole pine	1,350	S	Severe	Moine schists ..	Peat 1 to 5 ft. deep ..	50–60	*Trichophorum caespitosum* and *Myrica gale/Molinia caerulea* or *Eriophorum vaginatum/Narthecium ossifragum*.
Carrick ..	Ayrshire ..	3	Lodgepole pine	1,200	NW	Severe	Ordovician shales ..	6 to 18 in. peat over stony clay, fairly compact.	60	*Nardus stricta/Eriophorum vaginatum*, also *Trichophorum caespitosum*, *Molinia caerulea*, etc.
Carrick ..	Ayrshire ..	4	Sitka spruce ..	1,400	S–SW	Severe	Ordovician shales ..	Deep peat, 2 to 3 ft. or more.	80–85	*Eriophorum vaginatum* and *Vaccinium myrtillus*, also *Sphagnum*, *E. angustifolium* and *Trichophorum caespitosum*.
Glentrool ..	Kirkcudbrightshire	14	Sitka spruce ..	250	E	Moderate	Ordovician shales ..	Over 3 ft. of peat ..	50	*Eriophorum vaginatum*, with *Trichophorum caespitosum*, *Calluna vulgaris*, etc.
Kielder ..	Northumberland	73	Lodgepole pine and Sitka spruce	1,100	S	Moderate	Lower carboniferous sandstones.	3½ to 5 ft. peat over sandy clay with sandstone fragments (ganister).	50	*Calluna vulgaris/Eriophorum vaginatum*. *Trichophorum caespitosum* and *Sphagnum* frequent.
Rosedale ..	North Yorkshire	6 7	Scots pine {Japanese larch Sitka spruce}	800	S	Moderate	Jurassic: Kellaways beds.	Podsol. 2 to 4 in. peat, pan at 5 to 13 in., yellow sandy loam below.	33–35	*Calluna vulgaris* dominant. *Erica tetralix*, etc.
Langdale (Broxa)	North Yorkshire	94	Japanese larch and Sitka spruce	600	SW	Moderate	Jurassic: Lower calcareous grit of Middle Oolite.	1 to 2 in. peat over podsol, pan at 6 to 13 in. over yellow sandy loam.	30	*Calluna vulgaris*. *Ulex europaeus* and seedlings of *Betula* and *Pinus* before burning.
Allerston (Harwood Dale)	North Yorkshire	44	Lodgepole pine	700	NW–SW	Moderate	Jurassic: Estuarine beds of shale and sandstone.	3 to 6 in. peat over sandy loam, clay/sand below with siliceous boulders.	25–30	*Calluna vulgaris*. Also *Trichophorum caespitosum*, *Juncus* spp. *Eriophorum* spp. *Erica tetralix*.

Table 35

Site Details—1955 Experiments

Forest	County	Expt. No.	Species	Elevation (ft.)	Aspect	Exposure	Underlying Geology (Drift often present)	Soil	Rainfall (in.)	Vegetation before planting
Lael (Ullapool)	Wester Ross ..	16	Lodgepole pine	250	W	Severe	Torridonian sandstone: Applecross group.	1 to 5 in. peat over very compact moraine.	50–60	Very much burnt. *Calluna vulgaris/Trichophorum caespitosum. Cladonia and Rhacomitrium*, also *Nardus stricta* and *Molinia caerulea.*
Teindland ..	Moray	88	Lodgepole pine	800	NE	Severe	Old red sandstone boulder till overlying the Basal conglomerate of the middle O.R.S.	3 in. peat over 1 ft. leached podsol, pan at 9 to 26 in., compact.	32	*Calluna vulgaris*, with *Trichophorum caespitosum* locally dominant.
Drumtochty	Kincardine ..	15	Japanese larch	1,000	N	Severe	Metamorphic: altered grits.	4 in. peat over 3 to 4 in. leached grey compact clay.	35	*Calluna vulgaris*, pure and vigorous.
Carrick ..	Ayrshire ..	6	Lodgepole pine	1,400	NW–NE	Severe	Ordovician shales ..	6 to 24 in. of peat over very compact and stony brown gravel soil.	80–85	*Eriophorum vaginatum/Calluna vulgaris/Trichophorum caespitosum* or *Calluna vulgaris/Nardus stricta/Vaccinium myrtillus.*
Glentrool ..	Kirkcudbrightshire	16	Lodgepole pine	1,400	W–NW	Severe	Ordovician shales ..	3 ft. or more deep peat	80–85	*Eriophorum vaginatum/Calluna vulgaris/Trichophorum caespitosum*, etc.
Wauchope ..	Roxburgh ..	5	Sitka spruce ..	950	NW	Moderate	Lower carboniferous calciferous sandstone.	Hill peat, 3 to 5 ft. deep. (Soil Survey, Sheet 17.)	40–45	*Calluna vulgaris/Eriophorum vaginatum/Trichophorum caespitosum.*
Kielder ..	Northumberland	75	Lodgepole pine and Sitka spruce.	1,000	W	Severe	Lower carboniferous sandstone.	3 to 6 ft. deep peat ..	45	*Eriophorum vaginatum/Calluna vulgaris.* Some *Trichophorum caespitosum* and *Sphagnum.*
Langdale (Broxa).	North Yorkshire	100	Japanese larch	675	S	Moderate	Jurassic: Lower calcareous grit of Middle Oolite.	2 in. peat over podsol, pan at 8 to 13 in. over light brown sandy loam.	30	*Calluna vulgaris* with *Erica tetralix. Trichophorum caespitosum* locally dominant. Seedlings of *Betula* and *Pinus.*
Allerston (Harwood Dale)	North Yorkshire	46	Scots pine ..	700	NW–SW	Moderate	Jurassic: Estuarine beds of shale and sandstone.	3 to 6 in. peat over sandy loam, clay/sand below with siliceous boulders.	25–30	*Calluna vulgaris.* Also *Trichophorum caespitosum, Juncus* spp. *Eriophorum* spp. *Erica tetralix.*

PRELIMINARY RESULTS OF EXPERIMENTS IN DRAIN DEEPENING IN TWO BORDER FORESTS

By G. G. Stewart

237.2

In the history of the afforestation of peat areas, draining intensity and depth as important factors for successful establishment and growth were soon realised, and the results of experiments testing these factors have been given by Zehetmayr (1954). Until comparatively recently, however, no work was done on the effects of deepening existing drains in pole crops. Windblow in the Duke of Buccleuch's pioneer Border hill plantation at Moorburnhead, Dumfriesshire, in the period 1945 to 1948, and in Newcastleton Forest, Roxburghshire, in 1948, brought to notice the very shallow rooting of Norway and Sitka spruce in these woods, in which the spruces formed about nine-tenths of the crop. The roots were ramifying only in the layer of peat which was six to nine inches deep, and not penetrating into the clay which lay underneath. When a tree was windblown the widely spreading roots stripped the peat from the clay in a flat plate, thus exposing the clay, and the resulting wide shallow hole filled with water.

It was realised that in the Border hill area, with its good quality *Molinia* peat overlying clay, windblow could become a very serious problem if the roots could not be induced to penetrate, and to remain living in, at least the upper layers of the clay. A large-scale programme of drain-deepening, in an attempt to lower the level of the water in the soil and thus permit the roots to go down farther, was begun in the Border Forests, and at the same time (1949) two experiments were laid down—one at Newcastleton (Exp. 12/49) and one at Kielder, Northumberland (Exp. 54/49)—to try to assess the effects of drain deepening.

The objects of these experiments were as follows:

"(1) To see what effect drastic drain deepening would have on the level of the water table in hitherto poorly-drained stands of spruce.

(2) To follow, if possible, any effect of this drastic drain deepening on the development of the crop."

Owing to the comparatively small areas treated it was not expected that any observations could be made on the incidence of windblow.

The crops chosen were of Sitka spruce and they were considered typical of many thousands of acres in the Border country; the rate of growth however, had been a little slower than might be considered the average. Details of the sites and crops are given in Table 36.

The experimental treatments were as follows:

Drains deepened to 24 inches (Deepened).

Drains left untouched (Control).

Each plot in both experiments consisted of the two areas lying between three parallel drains. At Newcastleton, drains were 8 to 18 feet apart and at Kielder 15 to 20 feet apart. In the deepened plots three drains were opened for up to 50 yards in length; the areas bounded on one side by a Deepened drain and on the other by a Control drain were regarded as buffers between plots.

The method of assessment for the first object (water table level) was the measuring of the water level in inspection pits situated mid-way between two drains. These pits were about 9 inches square and 24 to 36 inches deep. The pits were dug in two transects—an upper transect and a lower transect; one pit was dug between each drain in each transect, which gave four pits in each treatment. The water table was taken as the depth of the level of the water in the pits measured from the surface at a fixed point. After a series of preliminary measurements, readings of the water levels were taken at intervals of two weeks from June, 1952 (August at Kielder) to February, 1955 (March at Kielder). The results of these measurements, from October, 1952 until the end of the series, were graphed and an extract for a six months' period from one transect at Newcastleton is given in Fig. 4. This extract shows the variation in the levels between readings, and the close relationship at all times between Deepened and Control. The graph for Kielder follows a similar pattern except that there is a consistently greater difference between the two treatments. Means of all the measurements are shown in Table 37.

Table 36

Details of Sites and Crops

Experiment	Newcastleton (Expt. No. 12/49)	Kielder (Expt. No. 54/49)
Location	OS 1 in. (Scotland) Sheet 85; grid ref. 529865.	OS 1 in. (England) Sheet 76; grid ref. 718842.
Topography	Near top of rounded hill ridge.	Smooth slope on side of hill.
Aspect and slope	Gentle slope to north east.	
Exposure	Moderate.	
Elevation	890 ft.	800 ft.
Geological formation ..	Scottish calciferous sandstone series of Carboniferous age.	
Soil	6–15 in. peat overlying grey brown clay.	4–24 in. peat overlying grey brown clay.
Vegetation at time of planting	Calluna/Molinia	
Vegetation in 1949	Nil. In small open patches—Sphagnum and *Polytrichum commune* on drain sides. Strong growth of *Molinia* at edges of Compt.	Nil. Strong growth of *Molinia* at edges of Compt.
Land use before planting ..	Sheep grazing.	
Crop	Sitka spruce planted 1927 on turfs at a spacing of 4½ ft. by 4½ ft.	
Quality Class	Q.C. V.	

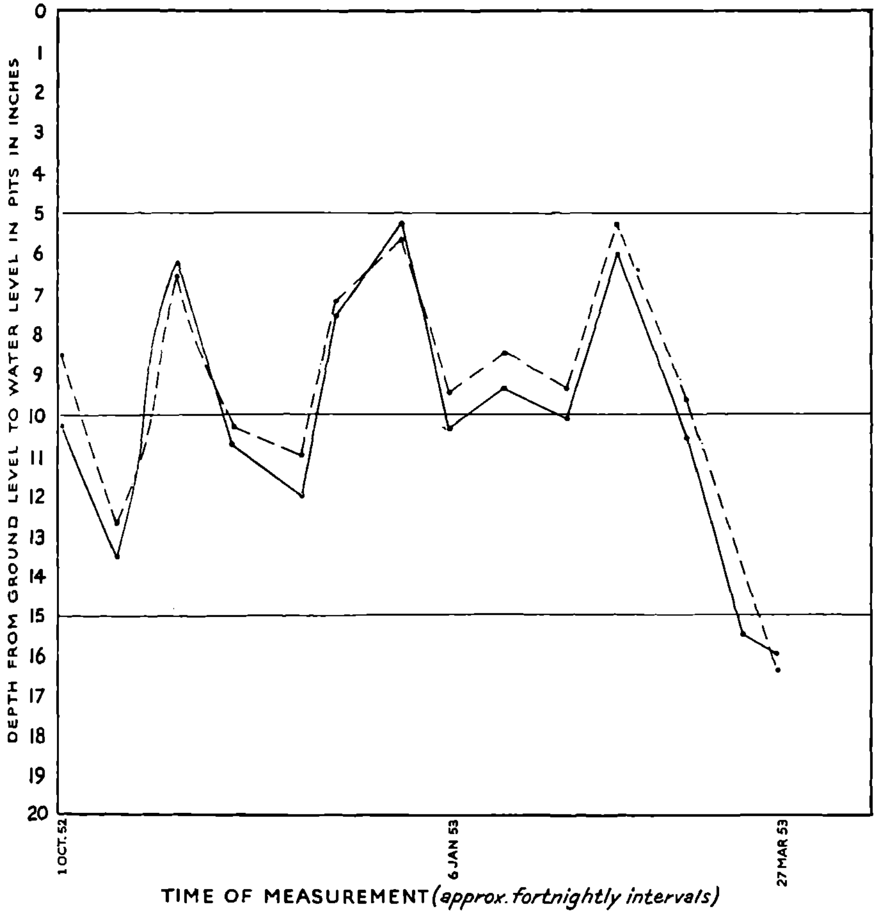


FIG. 4. Extract from Graph of Water Levels in Inspection Pits; Newcastleton, Upper Transect. N.B.—Dotted line ...... represents Control. Full line ——— represents Deepened.

Table 37

Water Level Depths (inches) in Inspection Pits

Experiment	Lower transect		Upper transect		Means		Remarks
	Control	Deepened	Control	Deepened	Control	Deepened	
Newcastleton	7·4	8·2	8·7	8·9	8·1	8·5	S.E. ± 0·31; Not sig.
Means ..	7·8		8·8		—		
Kielder ..	14·9	21·1	15·2	18·9	15·1	20·0	S.E. ± 0·75; Diff. for sig. at 5% = 2·3; Diff. for sig. at 1% = 3·2
Means ..	18·0		17·0		—		

From this table it can be seen that there is a great difference between the results at the two sites. At Newcastleton, the deepening of the drains has had little or no effect on the water table, as judged by the level of the water in the inspection pits. At Kielder however, the water level has been consistently lower in the pits between the Deepened drains and these differences are highly significant.

In 1952 it was decided to try to find the water table profile between drains, and a number of further inspection pits were opened at Newcastleton on either side of some of the main pits, to give a line of four or five pits between drains; thus, the line of pits covered a distance of 14 to 18 feet. Measurements of the water levels in these pits were made from September, 1952 until the end of the main series of measurements in 1955, and the results are shown in Figs. 5 and 6.

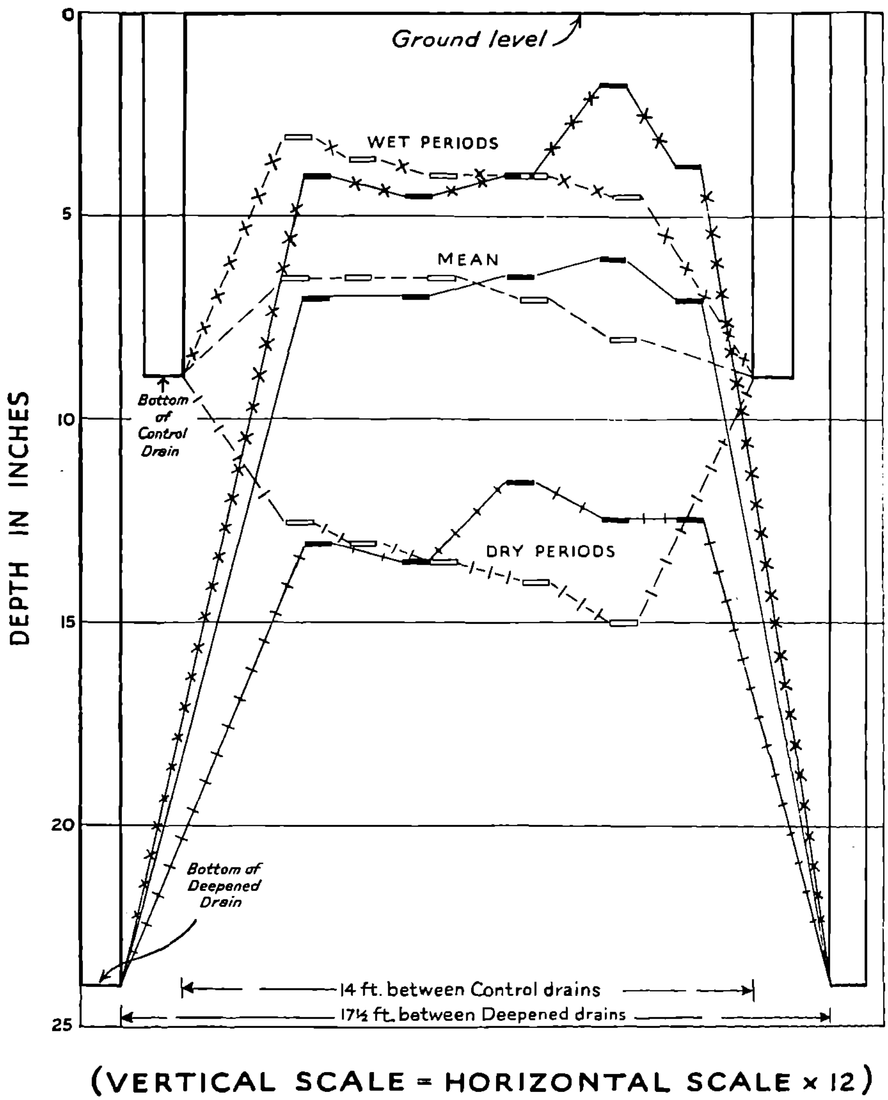


FIG. 5. Water Table Profiles between Drains; Newcastleton, Lower Transect. For Key to Symbols, *see* opposite.

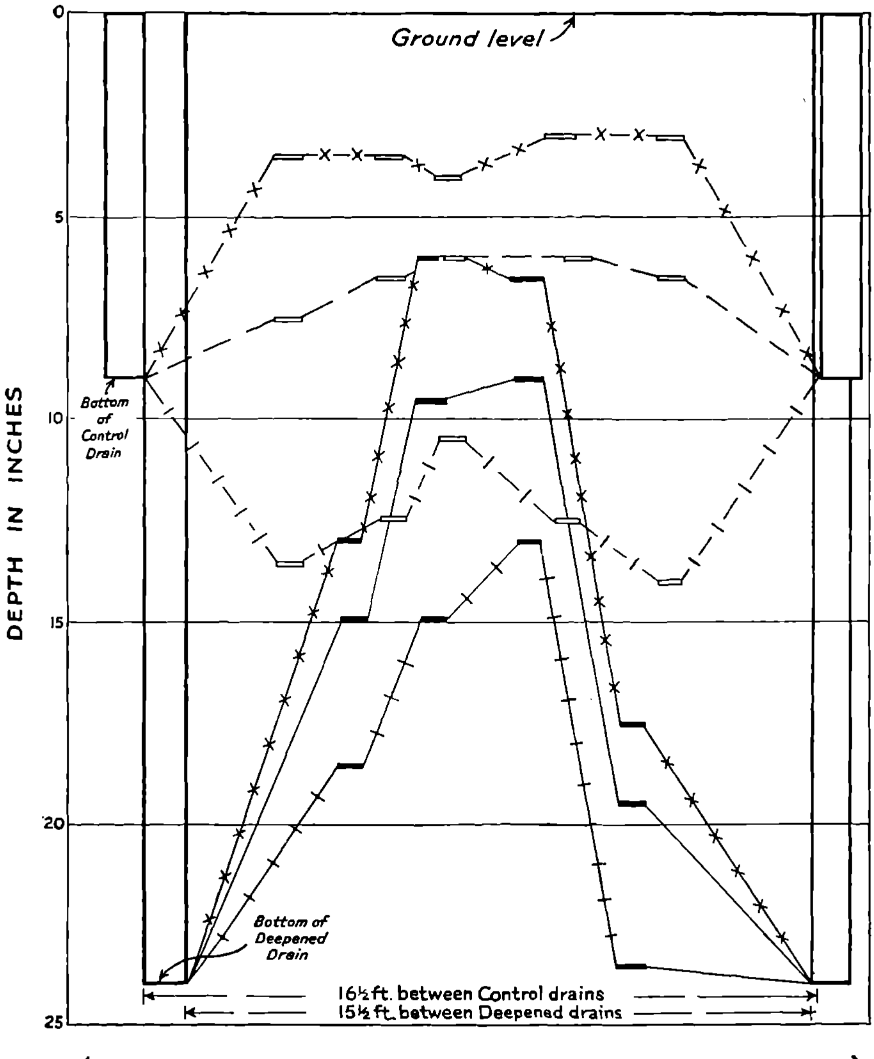


FIG. 6. Water Table Profiles between Drains; Newcastleton; Upper Transect. For Key to symbols, *see* below.

KEY to figures 5 and 6

▭	Water level in pits between Control drains.
▬	Water level in pits between Deepened drains.
—x—x—	Water profile between Control drains during very wet periods.
—✕——✕—	Water profile between Deepened drains during very wet periods.
— ǀ — ǀ —	Water profile between Control drains during very dry periods.
—+——+—	Water profile between Deepened drains during very dry periods.
— — —	Water profile between Control drains (mean of all readings).
———	Water profile between Deepened drains (mean of all readings).

Criterion for "very wet periods"—water level less than 5 in. below ground level. Criterion for "very dry periods"—water level more than 10 in. below ground level.

Fig. 5 for the lower transect shows that the water table within the middle 9-feet-wide strip remained at about the same level between the Deepened drains as between the Control drains, that is, at a depth of about 4 inches in wet periods, and about 13 inches in dry periods. In the upper transect (Fig. 6), the Deepened drains have had an effect over the whole area between the drains; half way between the drains, the water level is 2 to 3 inches below the level in the pits situated between the Control drains. A further point of difference between the transects lies in the shape of the profiles. In the lower transect, the water levels in the pits nearest the drains show no increase in depth compared with those farthest from the drains. Consequently, the lines drawn from the edge pits to the bottoms of the drains (Fig. 5) cannot be taken as true profiles. In the upper transect, however, a definite profile has been formed between the Deepened drains (Fig. 6). In this transect, the Deepened drains have altered the water table for 6 to 7 feet inwards.

Table 38

Height Increment (feet) over Four Years at Kielder and Five Years at Newcastleton

Experiment	Lower transect		Upper transect		Means		Remarks
	Control	Deepened	Control	Deepened	Control	Deepened	
Newcastleton	6·7	7·0	6·2	6·4	6·6	6·7	S.E. ± 0·21 Not sig.
Means ..	6·8		6·3		—		
Kielder ..	6·6	6·6	7·0	7·4	6·8	7·0	S.E. ± 0·29 Not sig.
Means ..	6·6		7·2		—		

Table 39

Girth Increment (inches) over Four Years

Experiment	Lower transect		Upper transect		Means		Remarks
	Control	Deepened	Control	Deepened	Control	Deepened	
Newcastleton	1·6	1·8	1·6	1·6	1·6	1·7	S.E. ± 0·08 Not sig.
Means ..	1·7		1·6		—		
Kielder ..	2·0	2·0	1·9	2·4	2·0	2·2	S.E. ± 0·10 Not sig.
Means ..	2·0		2·2		—		

To fulfil the second object (growth of the crop), three dominant trees adjacent to each row of pits (each single pit at Kielder) were selected and measurements made of top height and girth at breast height. Two assessments were carried out, the first at the end of the 1950 growing season (1949 for height at Newcastleton) and the second at the end of the 1954 growing season. The results of these measurements are given in Tables 38 and 39.

From these tables it can be seen that the Deepened plots have given equal or better growth for both height and girth. None of the differences however, is significant, and there are anomalies at each site; for example, there are significant differences between blocks at Kielder for which no explanation is evident. However, the general trend over the four-year period is of interest.

The experiment at Newcastleton has now had to be closed, but the future development of the crop at Kielder will be followed for a further period, after which the development of the roots will be examined.

The conclusions formed from these experiments up to the present, may be summarised as follows:

(1) The deepened drains at Kielder have reduced the water table as measured by the water levels in the inspection pits by about five inches; this result is statistically highly significant. At Newcastleton, the deepened drains have had no effect on the water table.

(2) At Newcastleton the water table profile in one transect between deepened drains (24 inches deep) was similar to that between control drains (nine inches deep). In the second transect, the profile between the deepened drains was a few inches below that in the control.

(3) Over a four-year period, the height and girth of selected dominant trees have not been materially affected by drain deepening to 24 inches.

REFERENCES

ZEHETMAYR, J. W. L. 1954. *Experiments in Tree Planting on Peat.* Bull. For. Comm. (22), pages 30–31.

ESTABLISHMENT OF A SEED ORCHARD FOR THE PRODUCTION OF HYBRID LARCH SEED

By A. F. MITCHELL

Introduction

232.311.3

The hybrid larch, *Larix eurolepis* Henry, has been in cultivation for about 50 years and has shown itself to be one of our fastest growing trees (Lines, 1957). At its best, the vigour, habit of growth, disease resistance and hardiness of the hybrid are superior to Japanese larch and considerably superior to European larch of the average Scottish provenance (Edwards, 1956). The greatest expression of these desirable characteristics is found among first generation hybrids, i.e. when the cones are collected from one or other of the parent species, and many tree breeders are making selections among Japanese and European larch and laying down seed orchards to produce the hybrid on a large scale.

In the seed orchard described in this article, the parent trees are represented by clones of grafted plants which are genetically identical with these trees. This procedure has several advantages:

(1) The parent trees can be outstanding trees growing in any part of the country, while the seed orchard can be sited in an area favourable to seed production.

(2) The parent trees can each be represented any number of times so as to produce any quantity of pollen or female flowers and cones.

(3) Controlled pollinations can be easily carried out with the object of testing all the possible parental combinations in the orchard and finding which combinations produce the best progeny.

Selection of Parent Trees

The hybrid was first noted at Dunkeld, Perthshire, and much of the hybrid larch seed has been derived from the Japanese larch trees bordering the avenue to Dunkeld House, the pollen having presumably come from some European larch trees growing close by. The basis of the seed orchard has therefore been the phenotypically best of the trees of both species at Dunkeld and certain other outstanding phenotypes or plus trees selected in Angus, Kirkcudbrightshire, Herefordshire and Monmouth.

Phenotype implies the external appearance of an individual; or the expression of its inherent character modified by the environment.

The Japanese Larches

The best of the trees on the Dunkeld avenue, for vigour, habit and stem-form were selected, four being used, i.e. numbers 2, 3, 8 and 10 (see Matthews, 1954). East of the avenue is another fine tree of the same age and origin, but taller and larger in girth, and this was included. The two best of several good and very large Japanese larches near South Lodge, Glamis Estate (Angus) were chosen and three with good stem form and light branching were selected in Compartment 2, Dalbeattie Forest, Kirkcudbrightshire. These very lightly-branched trees should offset the tendency to the heavier branch system of the Dunkeld trees. Finally, two trees of outstanding vigour and stem form from Mortimer Forest, Radnorshire, were added, making 12 Japanese larch in all. The dimensions of all these trees are shown in Table 40.

The European Larches

Hybrids raised from the Japanese trees on the avenue at Dunkeld must have had for pollen-parents either some small European larch immediately behind the Japanese larch, or some of the big old trees on Kennel Bank, which stand above and 50 yards to the west of the Avenue. Assuming the latter to be more likely (mainly on the grounds of pollen production) the best of the 14 trees was selected. This is tree 6 which is an outstanding specimen and among the finest larch stems in Europe. A second European larch, from Tintern Forest (Monmouth) was included for its remarkably fine branches and narrow crown, which contrasts sharply with that of the Dunkeld Japanese larches. The third and last European larch chosen was a vigorous young tree from Glamis, since neither of the other two European larches is very vigorous in comparison with other Plus trees (see Mitchell, 1956).

Table 40

The Dimensions of the Parent Trees

Tree Number	Origin	Age	Height (feet)	Girth (feet)	Girth (inches)	Date of Measurement
EL 6	Dunkeld, Kennel Bank ..	207	130	10	2	1957
EL 120	Tintern forest	100	102	5	8	1951
EL 141	Glamis Estate	59	105	5	11	1954
JL 2	Dunkeld Avenue ..	68	77	7	9	1955
JL 3	Dunkeld Avenue ..	68	84	6	1½	1955
JL 8	Dunkeld Avenue ..	68	93	6	8	1955
JL 10	Dunkeld Avenue ..	68	85	5	9	1955
JL 12	Dunkeld, East of Avenue	68	98	8	5½	1955
JL 20	Glamis, S. Lodge ..	62	95	7	0	1957
JL 21	Glamis, S. Lodge ..	62	95	7	0	1957
JL 40	Dalbeattie Forest ..	31	63	2	5	1955
JL 41	Dalbeattie Forest ..	31	64	2	3	1955
JL 42	Dalbeattie Forest ..	31	61	2	5	1955
JL 50	Mortimer Forest ..	32	73	2	10½	1955
JL 52	Mortimer Forest ..	32	78	3	0	1955

Site and Layout

Site

The site of a seed-orchard for larch requires favourable conditions of temperature, rainfall and sunshine, a low record of spring frosts and a soil of high nutrient status which is yet light enough to be worked on during pollination in early spring, without compacting. Good air drainage and some degree of isolation from plantations of larch are also required. As the larches bear seed as far north as they are grown in Britain, latitude was not regarded as important in itself and a site at Newton Nursery, near Elgin, Morayshire was chosen. This slopes gently to the northwest, is four miles from the sea and is underlain by Old Red Sandstone, which gives rise to a freely-draining soil. The area had been used for raising transplants until a few years before, and then was partly under greencrop or potatoes and partly fallowed. The pH is 5·5 and organic content 7 to 8·5 per cent.

Isolation from Plantations and Trees of the Same or Related Species

There are plantations of pure larch of over one acre in extent some 2,000 yards from the seed-orchard, and mixed plantations of larch and other species some 1,200 yards away. Foreign pollen arriving at the orchard site was assessed in 1951, and then reached about five per cent at maximum contamination. Since then several single larches within 600 yards have been removed. There are now no unselected larches within 600 yards (although there are other larch seed orchards nearby) and contamination from unselected trees should be negligible.

Treatment of the Site

In 1951 a greencrop was ploughed in and the area harrowed. From then on it was kept harrowed and weeded until September, 1954 when it was grassed down. The grass mixture used consisted of "S23" perennial rye grass, Crested

Dogs Tail grass, Creeping Red Fescue grass and Kent Wild White Clover. After four years of twice-yearly mowing there is a small proportion of such grassland weeds as *Bellis*, *Prunella*, and *Senecio jacobaea* in the sward. An area one yard square has been kept hoed around the grafts, the chief weeds being *Rumex acetosella* and *Claytonia*.

Design of the Seed Orchard

The orchard, which is four acres in extent, contains 768 seed trees. The grafts of each parent tree are in rows, and the orchard may be described as being in three parts. In each part one of the three European larches is represented by four rows of 30 grafts each, the rows being 30 feet apart and the grafts being 15 feet apart within the rows. Between these rows of European larch are grafts of the Japanese larches, three parents per row and ten grafts of each parent. So each European parent has ten grafts adjacent to ten grafts of every Japanese parent. See Diagram 1.

Diagram 1

Layout of Seed Orchard

EL	6	6	6	6	6	6	6	6	6	6	6	6	6.......... 6.... 6
JL	12	12	12	12	12	12	12	12	12	12	20	20	20 20......42....42
EL	6	6	6	6	6	6	6	6	6	6	6	6	6.......... 6.... 6
JL	21	21	21	21	21	21	21	21	21	21	40	40	40..........50....50
EL	6	6	6	6	6	6	6	6	6	6	6	6	6.......... 6.... 6

Note: The numbers above refer to clones. See Table 40, page 139, for details of parent trees.

The spacing given by this layout is 15 feet each way. However, the grafts began to flower profusely when they were only five years old, and there is still a great deal of growing space available. At least twice as many plants per acre could be grown for perhaps ten years without crowding, and this would double the number of flowers likely to be available for the critical early crossing work and would in addition speed up the production of a good pollen cloud. It is now the practice with larch to plan Seed Orchards at 15 feet by 7½ feet, using a layout which permits removal of half the plants in a thinning, without altering the proportion of the parent trees present.

Establishment

The Grafted Seed Trees

In March, 1951, grafts of most of the Plus parent trees were made with scions got from the trees in February of the same year. The scions were grafted on to one-plus-one transplants of Japanese larch raised from imported seed, the work being done at Newton, Edinburgh, Grizedale (Lancashire) and Alice Holt. In November, 1951, the lorry carrying the grafts by road from the south was involved in an accident which caused many losses and made many grafts unusable due to loss of identity. More grafts were made, some on rootstocks of European larch, and these were planted in November, 1952, but survival was not good.

In 1953 a big beating-up programme was carried out, partly with plants grafted under glass and partly by means of grafting on Japanese larch rootstocks planted in position in the Seed Orchard the year before. The latter made much better growth than the former. Due to occasional deaths since 1954 there are still some losses to replace.

The Growth of Grafts

There has been a marked specific difference in the growth of the grafts, which is only partly due to the fact that the scion material of the Japanese larch, coming from younger, more vigorous parent trees, tends to be stronger and better material. This fact may explain why the Japanese grafts tend to get away to a better start, but the habit of growth is different even when the European larch grafts are made with strong scions. Graftings of Japanese larch produced a good leader from the start; they grew steadily and each clone is very uniform in growth and appearance. The European larch grafts in many cases took several years to develop a leader, especially those grafts which were produced under glass or on the open nursery and then transplanted into the seed orchard.

The grafts of "E.L. 6", however, which survived from 1951, made rather sinuous leaders and were about six feet tall after four years growth. Now, after six years of growth, these are about ten feet tall, as are the best clones of Japanese larch.

Staking the Grafted Seed Trees

To encourage the development of a leading shoot, the strongest shoot of some grafts, without evident leaders, were tied to stakes. As they grew these grafts lacked rigidity and still required stakes of ever-increasing size. Even those grafts with good leading shoots seemed to need some support because the site is at present somewhat exposed to northerly winds. So in 1955 ten-foot stakes were set up throughout the seed orchard. By 1957 many grafts had reached the top of their stakes, and appeared as pliant and un-firm as ever, with leading shoots much diverging from the vertical. So it was decided in summer 1957 to remove all stakes except in special cases of pronounced lean. Surprisingly, there were only two cases of damage from wind, and by spring 1958 the grafts were firm and rigid. The best policy appears to be to tie-in and support a shoot only where there is no evident leader, and then for a maximum period of two years.

Flowering and Cone Production

Phenology

The genetic composition of the seed produced by this seed orchard will depend on the relative times of female and male flowering of each clone. For example, the study of flowering dates of one tree in Perthshire and another in Monmouthshire does not give much indication of how they will react when placed together on the same site in Morayshire, so it was a matter of great interest how the different clones would flower.

In 1956, a year of exceptional flower-production, the pattern was as shown in Diagram 2.

Diagram 2

Periods During 1956 when Female Flowers were Receptive and Male Pollen was Being Shed

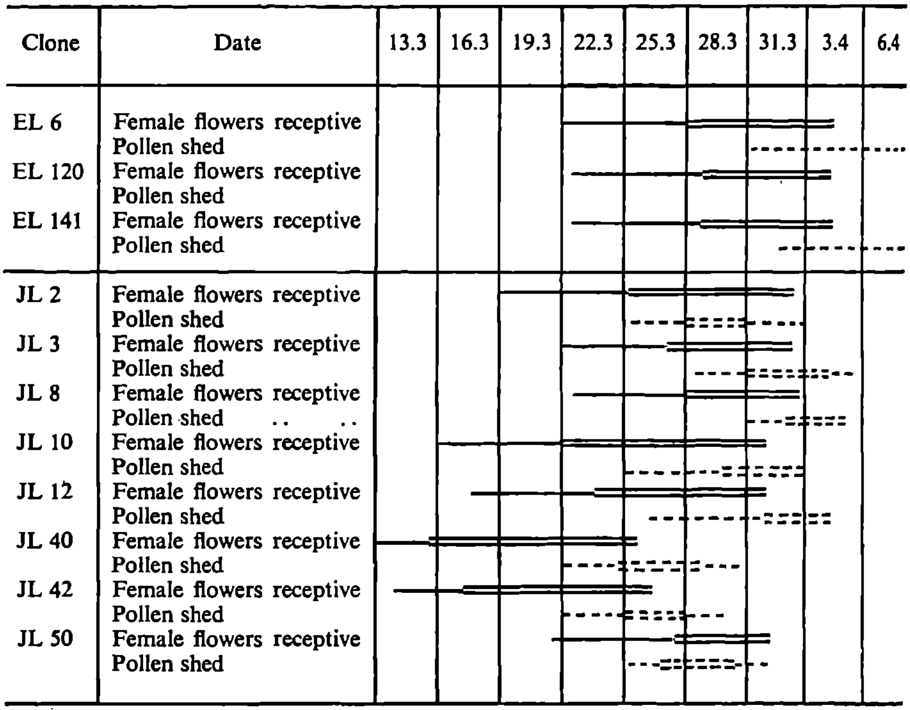


Diagram 2 shows that all the clones were protogynous by seven days or more, and that although the female flowers of both species generally occur together pollen is being shed by the Japanese larches by up to a week before the European larches start shedding. It follows that if this is the normal flowering pattern, the cones collected from the European larches will contain hybrid seed while those on the Japanese will contain Japanese larch seed. Therefore, to increase the production of hybrid seed, an increase in the female flowering of the European larches is called for.

In 1958 those clones that did flower behaved in the same relative fashion, but flowering was much later than in 1956, there having been heavy snowfall on 24th March and strong winds only a few degrees above freezing point until the 28th. See Diagram 3, opposite.

Flowering and Cone Production

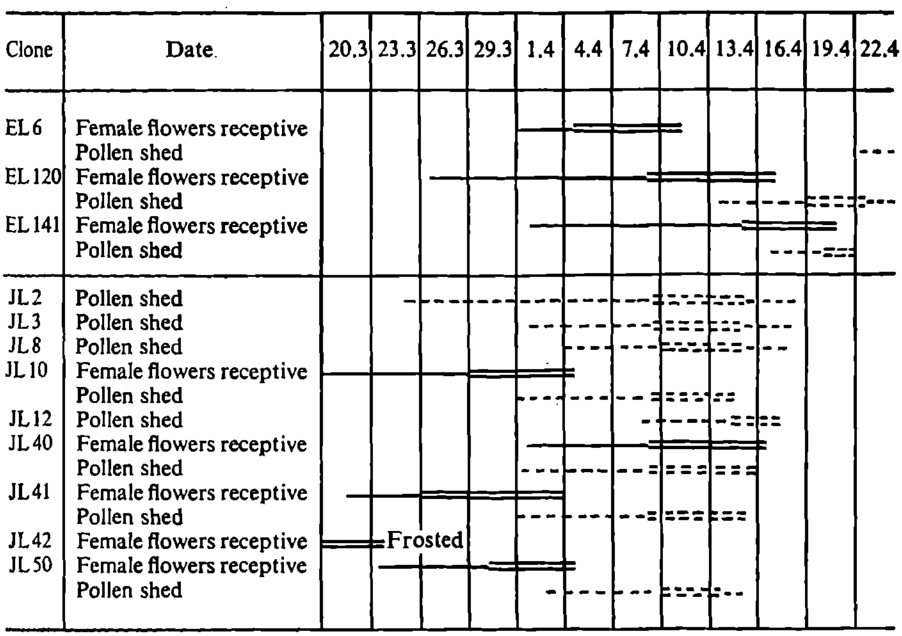
A few grafts planted in 1951 and 1952 ripened a few cones in 1954. In 1956, however, flowering was widespread and frequently very heavy on these grafts. Cones were ripened on 284 of the 718 grafts then present. The flowering and coning behaviour of some of the clones in 1956 is summarised below.

EL 6 Dunkeld	..	All the large grafts coned but only the largest produced any pollen. Maximum number of cones on one graft, 89.
EL 120 Tintern	..	Cones on large grafts only (maximum 11). No pollen.
EL 141 Glamis	..	Cones on seven big grafts only (maximum 45). Pollen on only four of these.

JL 2 Dunkeld	Cones on 29 out of 30 grafts (maximum 139). Pollen flowers densely clustered on all small twigs, to 3,000 per graft.
JL 3 Dunkeld	Cones on 13 out of 30 grafts (maximum 70). Moderate number of male flowers.
JL 8 Dunkeld	Cones on 28 out of 30 grafts (maximum 168). Moderate pollen production on some grafts only.
JL 10 Dunkeld	Cones on 23 out of 30 grafts (maximum 183). Pollen flowers abundant and densely clustered along trailing shoots.
JL 12 Dunkeld	All grafts coned, producing a total of 4,378 cones (maximum 407). Male flowers uniformly distributed and very abundant.
JL 40 Dalbeattie ..	Cones on 16 out of 30 grafts. These were small grafts, up to 4 feet 2 inches tall, but they coned heavily (maximum 227). Some bore only female flowers while others produced a moderate amount of pollen.
JL 41 Dalbeattie ..	All grafts coned, most of them being large and well grown. (maximum 70). Moderate pollen production.
JL 50 Mortimer ..	Cones on 22 out of 30 (large) grafts (maximum 322). Many grafts were entirely female and the cones were very densely placed. There was little pollen on any grafts.

Diagram 3

Periods During 1958 when Female Flowers were Receptive and Male Pollen was Being Shed



The specific difference in flowering behaviour is much more marked on the ground than the data suggests, and it follows the differences in vegetative growth. The European larches have developed mainly unbranched leading shoots, so there are few or no internodal shoots. The branching is sparse and the flowering-wood is strong and bears female flowers. Only in the largest and oldest grafts has there developed, low down in the oldest part of the crown, a system of weakly grown trailing shoots, and with few exceptions all the male flowers have been found on these.

The Japanese larch grafts have produced leading-shoots with many internodal twigs which soon develop into a dense system of small, pollen-bearing shoots. The nodal branches behave similarly, and there is abundant flowering wood carrying male flowers, while the female flowers (as in the European larch grafts) are largely placed along the main axes of the strong branches. This dense shoot system is most marked in clones JL 2, JL 3 and JL 10. In clone JL 12 the shoots are stronger, longer and less densely set, but the uniform abundance of the flowers and the large size of the grafts more than offsets the more sparse spacing of shoots and flowers. JL 20 and JL 21 have a much more open growth habit and have so far produced only a few flowers. JL 40 makes small, rather densely crowned grafts but in 1956 some of them grew cones on every shoot on the two-year wood of the main branches.

Weather and Flowering

The abundant flowering in 1956 followed the unusually hot summer of 1955. The summer of 1957 was also unusually hot but at different times and the difference in cone-production in the seed-orchard, then two years older, was very great. This may be in part a result of the big call on reserves needed to ripen the cones in 1956, on the grafts which coned that year. This difference is tabulated below (Table 41).

Table 41

Number of Cones and Pollen Production in 1956 and 1958

Clone	1956		1958	
	No. of cones	Pollen Production	No. of cones	Pollen production
EL 6	1,162	Very bad ..	35	Very bad (about same as 1956)
EL 120	53	None	277	Very bad
EL 141	204	Very bad ..	0	Very bad (more than 1956)
JL 2	1,399	Abundant ..	0	Abundant
JL 3	258	Moderate ..	0	Moderate
JL 8	758	Poor	0	Poor
JL 10	928	Abundant ..	29	Abundant
JL 12	4,378	Abundant ..	0	Abundant
JL 40	1,638	Moderate ..	0	Very bad
JL 41	576	Moderate ..	0	Very bad
JL 50	900	Moderate ..	5	Very bad

Note: Clones JL 20, 21, 42, 52 did not produce cones or pollen in either year.

From Table 41 it would appear that whatever difference there was in the weather between the summers of 1955 and 1957 was crucial to the production of cones by Japanese larch; important but not crucial to the production of cones by European larch, and of little consequence to the production of pollen in either species. The increase in the cones on clone EL 120 is due to the majority of the grafts, planted out in the spring of 1954, reaching flowering age or size by summer 1957.

Larch female flowers are identifiable under the microscope in August, and probable initials are visible by the end of July (Worsley, unpublished). If July were the critical period for the differentiation of female flowers at Newton, there should be some difference between the weather of July 1955 and July 1957. In fact, from the Monthly Weather Reports of the Meteorological Office, such a difference in the last three weeks of July is evident. July 1955 was warm, sunny and dry throughout, while July 1957 was warm and cloudy for the first week, then cool, cloudy and wet for the last three weeks. The figures in Table 42 below are mean figures derived from those for Kinloss (six miles to the west of Newton) and Elgin (three miles east of Newton), given in the Monthly Weather Report.

Table 42

Meteorological data for the Four Summer Months of 1955, 1956 and 1957 and Size of Cone Crop

Year	Month	Mean Max. Temp. (°F.)	Abs. Max. Temp. (°F.)	Sunshine (hours)	Rainfall (inches)	Cone crop in the following year
1955	May..	54·5	71·0	206	3·0	Very good
	June..	62·5	73·5	219	1·0	
	July	69·8	*80·5*	*252*	*0·7*	
	August	69·5	87·5	155	1·5	
1956	May..	59·6	72·5	171	0·9	Nil
	June..	59·0	71·5	184	2·4	
	July	63·9	71·5	180	5·6	
	August	59·1	70·5	146	3·7	
1957	May..	56·5	66·5	191	0·9	Nil
	June..	63·2	81·5	222	1·9	
	July	62·0	*69·5*	*86*	*5·5*	
	August	62·2	72·5	123	4·7	

Note: The cone crop data refer to cones JL 2 and JL 12.

From the figures available, there is little difference between May 1955 and 1957; June 1957 had a hotter spell than June 1955, but July 1957 was cooler and wetter and very much less sunny than July 1955. The inference is that middle and late July is the critical period of weather for female flower bud initiation at Newton.

The Induction of Flowering

To hasten flowering and, perhaps, lessen dependence on weather, much work is being done on methods of stimulating flowering. A number of grafts were planted immediately adjoining the Seed Orchard at Newton, for experimental work, and these were "topped", with varying degrees of severity, in spring 1957. This was in connection with wind-firmness and the development of a strong leading shoot, and also to test the effects on flowering of pruning larches using methods applied to fruit trees. In spring 1958 the main branches of five clones were tied in to the main stem to bring them into a downward pointing position, following the success of this geotropic treatment at Manchester University (Longman and Wareing, 1958) and Alice Holt.

The Crossing Programme

Before seed produced in the Seed Orchard is released for forest use, it is desirable that there should be under test some progeny of every combination of parents that can be produced. Advantage was taken of the good flowering of 1956 to do as much of this as possible, by controlled pollination. Over 5,300 cones were isolated in 1,100 bags. Of the possible hybrid combinations (72 if reciprocal crosses are included), 31 were made, 21 of them reciprocally. The three European larches were also crossed one with the other, but too few cones were produced for progeny trials. Of the 12 Japanese larches, eight flowered sufficiently to be crossed among themselves. In addition, these eight Japanese larch clones and the three European larch clones were all pollinated with their own pollen, i.e. self-pollinated, to determine the degree of self-fertility and the effects of inbreeding.

The cones were collected early in September 1956, and the number of good cones collected was 68 per cent of the number pollinated. Losses were due to breakage of the bagged shoots, and failure of some cones to develop. The numbers of seed extracted per cone varied enormously with difference crosses, but was fairly uniform taking the clones as a whole, with JL 10 lowest of the Japanese larches at 18 seeds per cone, and JL 52 highest with 56 seeds per cone. The European larch cones were probably picked a little too early, when still green, and produced very low numbers of seed, i.e. 8, 24 and 16 seeds per cone respectively. Germination of the seed, sown in spring 1957 at Alice Holt, was often surprisingly high when it is considered that an isolated female flower is given a few puffs of pollen lasting a matter of seconds only, whereas under forest conditions a flower is in air containing some pollen for up to two weeks. Evidently the vastly greater concentration of pollen from a pollen-gun outweighs the much shorter time. This also suggests that under forest conditions the pollen cloud is often very tenuous and insufficient for full pollination. Germination of the control-pollinated seeds reached over 70 per cent in a few cases. In most "selfs", and a few other crosses, it was nil.

The progeny of this crossing programme are now rising one-plus-one transplants at Alice Holt, and it is too early to say anything about their performance beyond noting that the hybrid JL 8 x EL 141, and its reciprocal, have given most promising and remarkably uniform progeny. The first full assessment of height growth in this replicated trial has been done, the results have been analysed statistically, and an assessment of height and basal diameter will be made when they complete the year as one-plus-one transplants. At that stage it is thought that real differences will be evident, and the results will then be reported. The plants will be planted out on sites chosen for their diverse conditions in replicated field experiments.

Summary

The composition, lay-out and establishment of the Newton Seed Orchard for the production of hybrid larch seed are described. The following conclusions are drawn:

(1) Establishment may take several years when grafts are moved in to a site. When possible grafting should be done directly on to rootstocks planted on the site. Strongly grown scion material is necessary.

(2) The orchard should be planted at at least twice the final density so that more flowers are available for testing in the first year of flowering and early yields of seed are increased.

(3) Grass sward should be established early for ease of working, control of nutrients and to prevent deterioration of the soil.

(4) Staking should only be resorted to when very necessary and then for a maximum of two years.

(5) At Newton the cone-production may depend greatly on the temperature in mid-July.

(6) Cone-production will thus probably be erratic and means of achieving a more even flowering are worth trying. Geotropic treatments involving the tying down of branches seem promising.

(7) Comprehensive progeny testing is required before seed can be released for general use in the forest.

REFERENCES

LINES, R., 1957. *Larix eurolepis* Henry, in *Exotic Forest Trees in Great Britain.* Forestry Commission Bulletin No. 30. H.M.S.O. 1957.

EDWARDS, M. V., 1956. The Hybrid Larch, *Larix x eurolepis* Henry, *Forestry,* 29, 1, 1956, 29–43.

MATTHEWS, J. D., 1954. *Japanese Larches at Dunkeld, Perthshire: A Study in Variation.* Forestry Commission, Forest Record No. 25. H.M.S.O. 1954.

MITCHELL, A. F., 1956. The Selection of "Plus" European Larch Trees. *Scottish Forestry,* 10, 2, 1956, 68–80.

LONGMAN, K. A. and WAREING, P. F., 1958, The Effect of Gravity on Flowering and Shoot Growth in Japanese Larch (*Larix leptolepis,* Murray). (In the Press.)

MONTHLY WEATHER REPORTS, *Monthly Weather Reports* of the Meteorological Office, H.M.S.O.

PRELIMINARY EXPERIMENTS ON THE USE OF TOXAPHENE AND ENDRIN FOR THE CONTROL OF SHORT-TAILED VOLES IN YOUNG FOREST AREAS

By G. D. HOLMES, R. M. BROWN and R. M. URE

149.32:414.12

The short-tailed vole, *Microtus agrestis* L., is essentially a grassland animal, with a marked preference for the dense low cover of rank grasses and herbaceous species commonly present in young forest plantations, derelict agricultural areas, and waste land. Forest planting operations almost invariably favour an increase in vole populations, owing to the unchecked growth of grass and general herbage following exclusion of grazing animals from the planted area. Under these conditions the vole population may rise to a high level, causing considerable damage to the planted crop. Vole numbers are subject to irregular cycles of abundance, rising to plague proportions under favourable conditions. In the past, high population levels have most commonly been of somewhat local occurrence in forest areas, but in 1956 and 1957, plague, or near-plague, population levels were reported in young plantations throughout western districts of the country.

The vole is almost purely herbivorous, grass being its major food material. However, it frequently turns to newly planted tree species as a source of food, particularly if the population is high and succulent herbage and grass growth is poor owing to season or drought conditions. The nature and severity of such damage varies greatly, but the most serious attacks are usually confined to young plantations less than five years old. Older crops are less vulnerable, and in crops which have closed canopy and suppressed the ground vegetation, damage is usually negligible. The most serious damage occurs through girdling of the main stems and lateral roots of young plants, and in severe cases the stem may be gnawed through completely, or the bark stripped off the greater part of the stem. In 1956–57, there were numerous instances of voles stripping the bark or eating off young plants within a few days of planting, and in some areas losses were such as to necessitate almost complete replanting. Under such conditions the activity of short-tailed voles constitutes a serious menace to successful forest planting, and widespread damage in the last two years has greatly stimulated the interest of foresters in methods of control and protection.

Relatively little experimental work has been done, but in 1956 the Forestry Commission Research Branch laid down a number of trials to assess the value of chemical repellents for protection of young trees. A wide range of repellent compounds, including tri-nitro benzene aniline, bone oil, resin, bitumen and eight proprietary compounds were tested for application to the aerial parts of young dormant trees before, or shortly after, planting. Treatment of plants in bulk before planting by dipping or spraying is the most attractive technique, as application costs are small compared with treatment of individual trees after planting. Results from the two major trials, which were planted in Wales, are unsatisfactory, as vole damage throughout the trial area was insufficient to permit critical comparisons of the test materials. However, there are indications that some compounds, notably tri-nitrobenzene aniline, "Arbinol", "Wiltex", and bone oil (the latter to stem bases *only*), may give useful protection against injury during the first season. This work is continuing in 1957 as the technique seems to have practical possibilities.

Control of vole infestations by the use of placed and baited poisons such as warfarin, zinc phosphide and red squill, has also attracted attention, but the techniques have proved somewhat laborious and expensive. Voles have been killed in considerable numbers in this way, but the general level of control in baited areas has been inconsistent and unsatisfactory. In late 1956, following encouraging reports from Germany, investigation of control methods was extended to include the use of Endrin and Toxaphene applied to the vegetation in infested areas. The details of the trials carried out with these materials in 1956 and 1957 are reported below.

Trials of Endrin and Toxaphene for Vole Control

Existing Published Work

Serious vole infestation in German forests, and the failure of traditional methods of control, led to extensive trials of several chemical methods in 1954 and 1955. The results are reported by Schindler (1955) and (1956), who indicated that the compounds Toxaphene and Endrin, which are widely known as insecticides, were highly effective for control of voles at application rates about five times those normally recommended for insecticide purposes. Overall dusting or spraying of these compounds to the vegetation in infested areas resulted in spectacular reductions in vole numbers. It appears that the animals are killed by oral poisoning within a few hours of treatment owing to their almost continuous feeding habit and consumption of large quantities of treated vegetation. Schindler concluded that a high degree of control was possible, the most economical technique being overall spray application of 4 to 6 kg. of 50 per cent Toxaphene emulsion, or 1·0 to 1·7 kg. 30 per cent Endrin emulsion, in 400 to 600 litres water per hectare. These rates are equivalent to 1·78 to 2·68 lb. active Toxaphene per acre, and 0·27 to 0·45 lb. active Endrin per acre. He also suggested that autumn was the best period for treatment, as breeding has ended, and the entire population can be controlled before the winter attacks on planted trees.

The risks of injury to other animals and birds, including game and domestic livestock, were discussed, and it was reported that no injurious effects were observed after treatment of several thousand hectares. It was suggested that the susceptibility of voles to the toxins, compared with other vertebrates, is associated with their exceptionally large feeding capacity in relation to their body weight. Fish are apparently very sensitive to the poisons, and contamination of water should be avoided. Other workers, notably Horsfall (1956) in the United States, and Perry (1957) in Britain, report successful control of voles in fruit orchards with Endrin sprays.

Preliminary Trials in 1956

Site 1, Kirroughtree

The first trial was carried out in September, 1956 at Kirroughtree forest, Kirkcudbrightshire, with the object of gaining first hand experience of the practicability and effects of the treatments. The site selected was occupied by a three-year-old crop of Norway spruce, which was severely girdled by short tailed voles.

Vegetation consisted almost entirely of rank grass growth which enclosed a labyrinth of vole runs.

Treatments

0—Control. No treatment.
1—Toxaphene 50 per cent emulsion applied at 2·25 lb. pure toxicant in 55 gallons water per acre.
2—Endrin 20 per cent emulsion applied at 0·5 lb. pure toxicant in 55 gallons water per acre..

Treatments were applied as overall sprays, using a pressure-retaining knapsack sprayer.

Layout. Unit plots were 30 yards by 30 yards, or approximately 1/5th acre, and laid out in two blocks of three plots, with untreated buffer strips 30 yards wide between all plots.

Assessments. The vole population on each unit plot was assessed by recording the catches in unbaited breakback traps laid shortly after treatment. In each plot, the traps were laid at 5-yard centres to give a regular grid of 5 rows of 5 traps = 25 traps per plot. The traps were assessed and re-set for three consecutive days following treatment, and the total catches recorded were as follows:

	Control	*Toxaphene*	*Endrin*
Block I ..	12	9	5
Block II ..	10	11	7

Most of the catches on treated plots were in the trap lines within five yards of the plot boundaries.

It was impossible to draw reliable conclusions from these results, but there was no doubt that both compounds killed a considerable number of voles, judging by the number of fresh corpses found on and near treated plots during trap assessments. However, the trapping figures do not indicate the proportion of the population killed, or the relative effectiveness of the two treatments. It seems that 1/5th acre unit plots are too small, and trap catches were probably complicated by invasion of plot margins and the edge trap lines by beasts from outside the treated area.

Site 2, Alton

An opportunity to lay down a second trial came in late November 1956 at Alton Forest, Hampshire, in an area of felled broadleaved woodland with a high vole population.

Treatments. Toxaphene and Endrin were used at the same rates as in the first trial at Kirroughtree, but applications were made with a portable spray boom operated from a "Plantector" power spraying unit mounted on a Land Rover.

Layout. Plots were larger, being 40 yards × 50 yards, approximately two-fifths acre, and were arranged in three blocks of three plots, with wide untreated buffer strips between plots.

Assessments. A population census using breakback traps was completed on each of four days following treatment. For practical reasons it was necessary to reduce the number of traps laid per plot to a single line of 12 equally spaced traps. The *total* catches during the four days of trapping were as follows:

Control	*Toxaphene*	*Endrin*
7	3	3

Once again, catches were small on all plots, but greater numbers were caught on controls than on treated plots. The evidence for a substantial effect was strengthened by the fact that in five days following treatment, 13 and 15 dead voles were recovered from Endrin and Toxaphene plots respectively, and no corpses were found on control areas. This evidence was still rather inconclusive, and it was decided to lay down a large practical scale trial in autumn 1957 on a suitable infested area.

Large-Scale Trials, Crychan, 1957

The Site. A suitable area was located at Crychan Forest, Breconshire. The site was planted with Japanese larch in 1954, and heavy losses due to vole damage has necessitated replacing more than 50 per cent of the original plants during 1955, 1956 and 1957. Vole activity was still high in late 1957, and it was estimated that a further 30 per cent of the crop will need to be replaced by new plants in 1958. Vegetation consisted of a complete grass cover, mainly *Festuca* and *Agrostis* species, providing ample low cover for voles. The area was not ploughed prior to planting, and the conditions were suitable for mechanised spray application.

Treatments. 0—Control. No treatment.
1—Toxaphene 50 per cent emulsion at 2·25 lb. pure toxicant in 50 gallons water per acre.
2—Endrin 20 per cent emulsion at 0·3 lb. pure toxicant in 50 gallons water per acre.

Toxaphene rates were similar to those in the first tests, but the endrin rate was reduced from 0·5 to 0·3 lb. toxicant per acre to conform with the lower limit of the range recommended by Schindler. Sprays were applied using a tractor-mounted 40-gallon sprayer, fitted with a 15-foot spray boom at the rear, 24 inches above ground level. With this equipment it was possible to spray on a swathe of 15 feet at 2 to 3 miles per hour, and spraying was completed at over one acre per hour, including time for turning the machine, and refilling, etc. In practice, non-experimental applications could be applied by this means at 1½ to 2 acres per hour.

Spraying was carried out on November 7th and 8th under near ideal cold, dry, low wind conditions. Spray drift appeared to be negligible. Protective clothing, eyeshields and masks were worn by all concerned in the spraying operation.

Layout. The area was marked out into unit plots 100 yards square = approximately two acres, the whole area of the trial being about 14 acres. Untreated buffer strips 20 yards wide were left between all plots.

Trapping Technique

The technique of trapping, as practised in the preliminary experiments, was not fully satisfactory, as there were too many instances of traps failing to spring properly, or springing without catching. Dr. D. Chitty of the Bureau of Animal Population, Oxford, was consulted, and he gave invaluable advice and a field demonstration, resulting in a marked improvement in the precise technique of setting and placing traps.

These points of technique are most important and are worth describing in detail. As before, unbaited "break-back" traps with a small 1 × ½ inch hinged platform were used. The advantage of the small platform is, of course, that there is little chance of the animal escaping as the body of the victim must be well over the trap before the set can be disturbed. Relying on touch alone, it is essential to obtain a very fine setting of the trap.

A heavily infested area contains enormous numbers of tunnels under the turf, usually two to four inches below ground level. Traps are best placed in the tunnels, which can be easily exposed by looking first for the typical "bolt holes" in the grass mat, then pulling away the turf. Disturbing the turf and clearing a space in the tunnel for the trap does not appear to affect the use of the tunnel. These creatures seem curiously single minded, and if one end of a tunnel is deliberately blocked, the vole clears it and continues to use the run as before. The traps were placed with the platform level with the floor of the tunnel, and at right-angles to the direction of run. If the trap is placed too high above the base of the tunnel, the vole frequently digs under the trap. Also, care must be taken that there are no obstructions to affect the action of the trap when sprung.

If no underground tunnel could be found at a required position, the trap was set in an "open" run. In all cases open runs and tunnels were checked for fresh grass fragments or droppings to ensure that the runs were in use. Flagged metal arrows were inserted in the ground to mark all trap positions.

Thirty-six traps, in 3 lines of 12, were set in each plot, with 20 yards between the lines, and 5 yards between each trap within the lines. This pattern of traps was located at the centre of each plot so that no trap was closer than 10 yards to the plot boundary. This meant that there was a minimum distance of 40 yards, of which 20 yards was untreated buffer strip, between traps in neighbouring plots.

Assessments—Prior to Spraying

An initial trap census was completed on October 10th and 11th, nearly a month before treatment, merely to estimate the population level. The following simple divisions were made as a general guide to population:

Per cent Catch in Traps Laid		*Population*
0–19	..	Low
20–39	..	Moderate
40–60	..	High
61+	..	Very high

Results of the pre-spraying trap census were as shown in Table 43.

These figures indicated a generally high population level, with the exception of the control plot in Block II.

Table 43

Per cent Catches in Thirty-six Traps per Plot One Month before Treatment

Date of Assessment	Control		Toxaphene		Endrin	
	Block No.					
	I	II	I	II	I	II
10.10.57	64	25	78	58	58	—
11.10.57	55	47	47	44	42	—
Average	59	36	62	51	50	—
Population level ..	High	Mod.	Very high	High	High	

Assessments after Spraying. Post-treatment trapping commenced one day after spraying, and traps were assessed, and reset when necessary, on each of the following five days; results are shown in Table 44.

Table 44

Per cent Catches in Thirty-six Traps per Plot during Six Days after Spraying

Date of assessment	Control		Toxaphene		Endrin	
	Block No.					
	I	II	I	II	I	II
November 11th ..	50	50	11	4	0	—
November 12th ..	50	50	17	4	0	—
November 13th ..	25	3	11	0	0	—
November 14th ..	53	25	11	0	3	—
November 15th ..	36	30	14	4	5	—
November 16th ..	17	19	14	0	0	—
Average	38	29	13	3	1	—
Population level ..	Mod.	Mod.	Low	Low	Low	

Spraying with Endrin and Toxaphene has clearly killed a large proportion of the population resident in treated plots. The trapping figures show both compounds to be highly efficient, although the results with Toxaphene in Block I were not so convincing as in other treated plots. The poorer results with Toxaphene in Block I are not understood, but the numbers caught on successive days are more consistent with the idea that the plot was subject to continuous reinvasion than the idea that a small residual population was being reduced by trapping.

Visual inspection of sprayed plots revealed little evidence of activity by voles. The runs appeared deserted and no fresh droppings were found. The whole population was apparently declining judging by the difference between vole catches in October and November on control plots. This point, and the persistence of treatment effects, were examined by a further trap assessment on December 22nd and 23rd six weeks after spraying, as shown in Table 45.

Table 45

Per cent Catches in Thirty-six Traps per Plot Six Weeks after Spraying

Assessment date	Control		Toxaphene		Endrin	
	Block No.					
	I	II	I	II	I	II
December 22nd ..	15	16	5	5	5	—
December 23rd ..	9	9	3	0	1	—

These figures confirm the general fall in population irrespective of treatment, but there still remains a very significant reduction in numbers caught on all treated plots.

Discussion and Conclusions

Practical Value. Both Endrin and Toxaphene at the rates tested resulted in drastic reduction in vole numbers. This intervention has undoubtedly prevented further serious damage to the planted tree crop, but it is also significant that the population on untreated areas has also fallen to a marked degree since the trial began. On balance it seems very likely that treatments such as these could be of real practical value under circumstances where severe vole injury was occurring.

Costs

The costs of the two chemicals were almost the same, viz.:

Endrin

At 0·3 lb. toxicant per acre
= 1·5 lb. 20 per cent emulsion at 13*s.* 5*d.* per lb.
= *20s. 1d. per acre.*

Toxaphene

At 2·25 lb. toxicant per acre
= 5·5 lb. 50 per cent emulsion at 3*s.* 8*d.* per lb.
= *20s. 2d. per acre.*

Assuming tractor spraying at the rate of one acre per hour attained in the main trial, total costs per acre can be estimated as follows:

	£	*s.*	*d.*
(1) Tractor and spraying equipment		15	0
(2) Tractor driver and assistant		6	6
(3) Water transport ..		5	0
(4) Chemicals	1	0	2
Total estimated cost per acre ..	£2	6	8

On very steep or broken ground, tractor spraying would be impossible, and spraying by man-mounted knapsack sprayers, or a portable sprayline from a vehicle-mounted power sprayer, would be necessary. In this event, application would be more costly, but it seems likely that costs could be reduced by cutting the total volume of fluid per acre, without detriment to treatment effectiveness. However, this should be confirmed, and meantime, the indicated treatment involves *overall* spraying at about 50 gallons per acre.

Toxicity Hazards and the Law

Both compounds have a high mammalian toxicity, and the method of overall treatment described involves risk of injury to any wild or domestic animals and birds feeding off the site. Nor is the risk of injury confined to herbivores, as predators, notably hawks, owls, foxes and weasels, may ingest toxic doses by devouring poisoned vole corpses. In the trials reported, no evidence of injury or fatalities amongst birds or animals, other than voles and shrews, was found. Schindler suggested that voles are exceptionally susceptible owing to the large amounts of poisoned herbage consumed in a short time.

In Germany, where the technique is practised on a large scale, the main precautions are to restrict applications to late in the season, excluding all grazing stock and dogs, and particular care is taken to avoid contaminating streams or waters containing fish life. The toxins are reported to persist in active form for three to four weeks on treated vegetation, and stock are excluded for this period at least.

Lange and Crüger (1957) have prepared an extensive review of the toxic side-effects of toxaphene and endrin applied for controlling voles. They concluded that autmn treatment with toxaphene at 1·75 lb. per acre or endrin at 2·14 oz. per acre, which are regarded as the minimum amounts for vole control in Germany, is unlikely to have undesirable far-reaching side effects on other living creatures. The application rates in the present tests were considerably higher than those described by Lange and Crüger, and further work is required to assess the toxicity hazards with lower rates under British forest conditions.

On present evidence, it is difficult to assess the actual risk of serious injury to wildlife. Much of the evidence suggests that the risk is very slight at suitable application rates and times, but until more extensive trials of low application rates can be completed, it is not proposed to recommend these treatments for large-scale practical use. The legal aspects of overall spraying of land with poisonous materials must also be considered, as if there is any appreciable risk to other animals and birds, the application could be an offence.

Summary

1. The results of preliminary trials of endrin and Toxaphene as toxins for controlling short-tailed voles are described.

2. First trials in 1956 at two forests indicated reductions in vole numbers on treated areas, but plot sizes were inadequate to give conclusive results.

3. The main trial in 1957 was carried out on two-acre unit plots, and results show generally high levels of control with endrin at 0·3 lb. and Toxaphene at 2·25 lb. per acre.

4. Costs of materials were approximately £1 per acre, the total costs with mechanical spray application being in the region of £2 10*s*. per acre.

5. Toxicity hazards to domestic animals, and wild birds and animals other than voles, are not fully known, and practical applications are not recommended until these hazards can be assessed in more extensive trials.

REFERENCES

HORSFALL, F., 1956. *Science* 123: 61.

LANGE, B. and CRÜGER, G., 1957. *Nachr.Bl. dtsch. Pfl. Sch. Dienst.* Stuttgart 9, pages 102–108.

PERRY, C. F., 1957. *Commercial Grower.* March 15th, page 548.

SCHINDLER, U., 1955. *Allge. Forstzeitsch.* 33/34, page 384.

SCHINDLER, U., 1956. *F.A.O. Plant Protection Bull.* IV. No. 5, pages 67–68.

SCHINDLER, U., 1957. *Der Forst- und Holzw.* 12(3), pages 1–6.

COMPARISON OF METHODS OF SAMPLING FOR THE MEASUREMENT OF MOISTURE CONTENT IN GREEN TIMBER

By R. S. HOWELL and D. KEMP

812.211:015.5

An extensive survey of the moisture content of fresh-felled conifer timber is being planned by the Utilisation Development Section to provide information on values of moisture content to be expected in consignments of roundwood. The small investigation described here was designed to help in choosing a sampling method suitable for the larger survey. Four methods were included, one being used as a standard by which the others could be judged. In this standard method the samples were complete 4-inch thick sections sawn from the log. The three trial methods were:

(1) Complete ½-inch thick discs.

(2) Pairs of opposite sectors cut from discs 1 inch thick. The width of each sector at the circumference was between 1 and 1·5 inches.

(3) Pairs of cores extending almost to the pith, taken with a standard Pressler borer. The cores were from the diameter perpendicular to that used for the sectors, and at a height three inches higher or lower than each pair of sectors.

The crop from which the trees were taken was of Quality Class IV pure Sitka spruce 31 years old, growing on a heavy clay soil at Alice Holt. One sample of each type was taken from each of 12 internodes of two dominant trees with breast-height girths of 28 and 30 inches. The sections, discs and sectors were sealed in individual polythene bags. The cores were placed in stoppered glass tubes. The balances on which the samples were weighed were accurate enough for weighing errors to be negligible compared with sampling and drying errors.

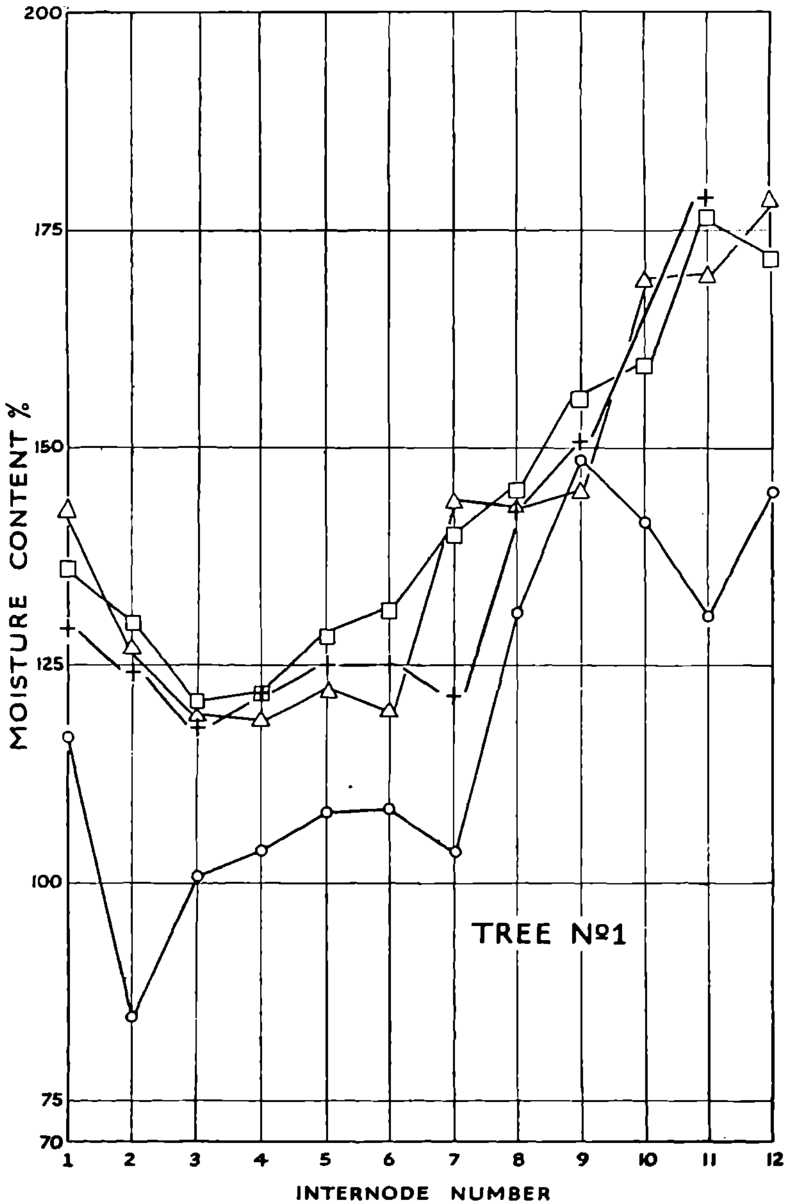


FIG. 7. Moisture Content Determinations by Various Methods at Various Positions up the Stem. Tree Number One. For Key to symbols see Fig. 8 overleaf.

The graphs, Figs. 7 and 8, show the results obtained by each method, plotted against the serial number of the internode for each tree. Points pertaining to sectors and cores represent the mean values of each pair of samples. The moisture content of the timber of these trees, defined as the weight of water in a given sample, expressed as the percentage of the oven-dry weight, clearly increased with the height of the internode, except for an initial decrease near the butt of the first tree.

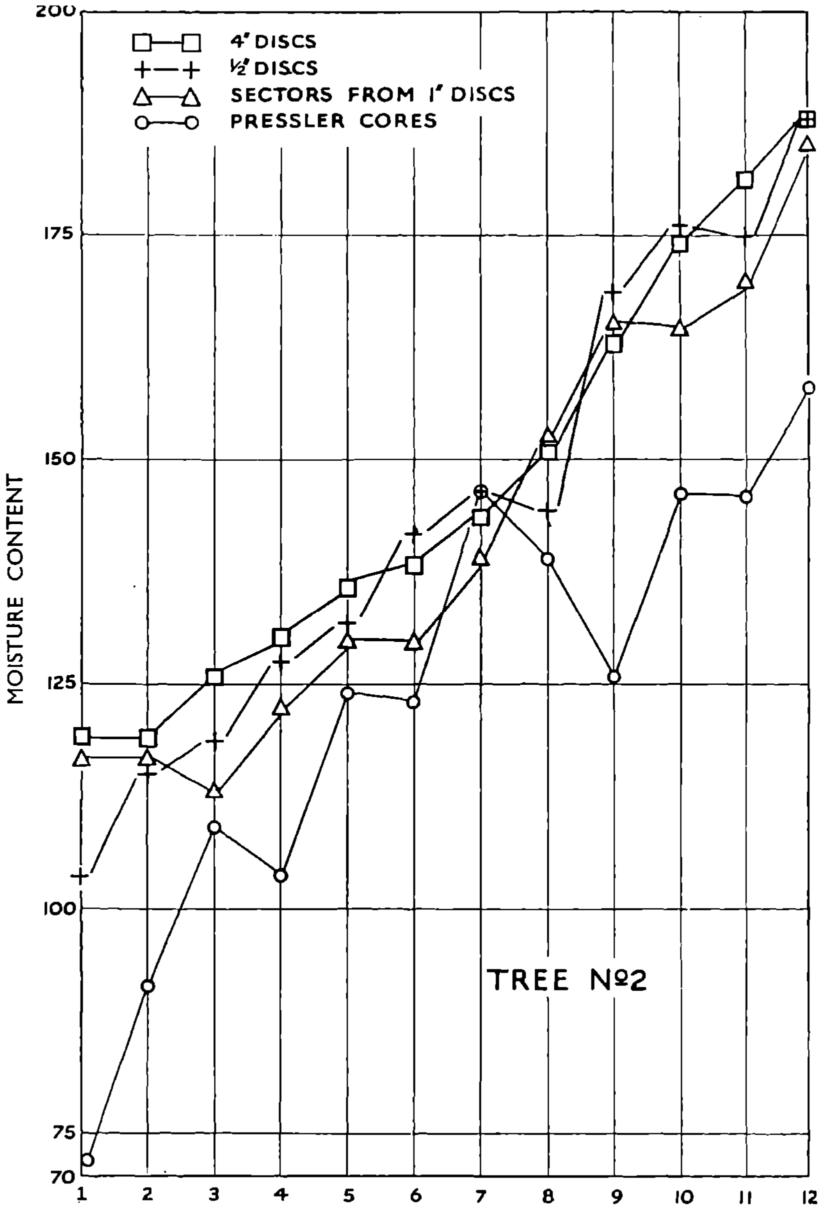


FIG. 8. Moisture Content Determinations by Various Methods at Various Positions up the Stem. Tree Number Two.

In the statistical analysis of the results, a number of assumptions were made, of which the most critical are stated here so that their importance and the consequences of their falsity can be judged. First, the convenient simplifying assumption was made that the errors involved in each method had two components; a constant one, the bias, arising from the process of measurement, and a random one, normally distributed with a variance characteristic of the method and arising from both sampling and measurement. Adoption of the 4-inch section method as a standard meant that this method was assumed to have no bias. The possibility of an average relative bias between the methods, due to a difference in the height at which samples were taken within an internode, was diminished by randomising the types of samples in four continuous-line Latin squares for each tree, each internode forming one row of a square. This first assumption would be untrue if, in particular, a change in the bias or the variance accompanied a change in the size of the samples (i.e. in the height of the internode). Though such a change seemed likely, an inspection of the graphs suggested that the effect was not large enough to invalidate the analysis. Secondly, it was necessary to assume that each method gave a valid estimate of the same moisture content in each internode. That is to say, the true moisture content of the material of all samples from one internode was assumed to be the same before sampling, apart from sampling error. The falsity of either of the above assumptions would have resulted in the probable overestimation of the experimental errors, especially for the methods using the smaller samples. It was assumed further, that between the true value of the mean moisture content of an internode and the serial number of the internode, there was a smooth relationship which could be represented adequately by an equation of the form

$$y = a + bx + cx^2 + dx^3 .$$

If this assumption alone were untrue, the variance of the random component of the errors of all methods would be overestimated by the same amount, and therefore in a comparison based on variance ratios, the less precise method would be favoured.

The analysis was directed to the comparison of the methods in terms of their bias, and the variance of their random error. The mean difference between the results of each method and the standard, is an estimate of the bias, and the error mean square about the cubic regression line for each method, is an estimate of the error variance. Stability in these characteristics over a series of trials is obviously a desirable property of any method. The only evidence which this experiment provided on this point, came from the difference between the estimates for the two trees.

The estimates are set out in Table 46.

Table 46

Differences in Moisture Content

Type of sample	Mean Difference (Moisture content %)		Error Mean Square (Moisture content %)^2	
	Tree 1	Tree 2	Tree 1	Tree 2
A. 4-inch sections	—	—	12	6
B. $\frac{1}{2}$-inch discs	$-9\cdot1\pm1\cdot7$	$-2\cdot5\pm1\cdot7$	21	26
C. Pairs of sectors	$-1\cdot2\pm2\cdot0$	$-5\cdot2\pm1\cdot4$	32	18
D. Pairs of cores	$-24\cdot5\pm3\cdot5$	$-23\cdot5\pm4\cdot0$	124	75

Under the assumptions made, these estimates are unbiased. Compared with the standard method, the use of cores gave results which were on the average 24 per cent too low, and which, moreover, had a comparatively low precision. The use of sectors and ½-inch discs also gave underestimates, but the bias of the sectors differed less between the trees than that of the ½-inch discs. This difference in the bias might have been due to an improved rate of working in sampling from the second tree, or to a difference in the degree to which the discs from the two trees were dried in the oven. None of the estimates of the variance of the random error of the methods differed significantly between the trees, and the estimates for the sectors and ½-inch discs for both trees were similar. These two methods gave results significantly more precise than the core method, and apparently less precise than the standard.

One feature of the results from the second tree has not been explained. This was the decrease in the slope of the regression line for core samples in the upper part of the tree. There was no suggestion that the same tendency was present in the first tree.

The trial methods studied in this experiment obviously have different applications. Cores will be useful, for example, when it is not convenient to fell many trees. A sub-sample of felled trees from which sectors or sections can be cut, should then be used for calibrating the whole series of observations on cores. The use of sectors has an advantage in sample size over discs and sections, and for some purposes its bias may be small enough to be neglected.

It may be noted that where the variation of moisture content within trees is to be studied, and an estimate of sampling error is necessary, it will not normally be sufficient to obtain this estimate from the deviation from the regression line, by assuming that the true relationship between height and moisture content can be represented by a simple polynomial, because if some samples taken from a knotty section are included, the relationship may be more complex than the one assumed. In the present investigation only knot-free samples were used, as we were interested in the accuracy of the methods, rather than in the estimation of the variation in moisture content within trees.

LOSS OF WEIGHT OF SMALL-SIZED HARDWOODS DUE TO DRYING

By E. G. RICHARDS

812.210

The experiment on the loss of weight of small-sized hardwoods carried out in the Forest of Dean in the spring and summer of 1955 (see *Rep. For. Res.*, 1956, page 162) was repeated in 1956. Oak, ash, beech, birch, sweet chestnut, sycamore and elm were weighed on the day of felling, and at monthly intervals from April to October.

On the day of felling the trees were cross-cut to give, for each species, 50 pieces, each 6 feet 6 inches long by 4 to 6 inches diameter under bark. After they had been weighed, the pieces were made into 14 cross-piled stacks, i.e. two stacks per species. One stack of each species was made under forest canopy and one in the open in a clearing in the forest. The stacks each contained five layers, each of five pieces, the bottom layer being raised off the ground on wooden bearers.

The stacks were reweighed at monthly intervals, care being taken to ensure that throughout the experiment each piece occupied the same relative position in the stack.

The moisture content of each stack was calculated from sample discs on the day of felling, using the formula:

$$\text{Fresh-felled moisture content percentage} = \frac{\text{Weight at time of cutting} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

Moisture contents were calculated at the end of the experiment, from the change in weight of the stacks (Table 47).

Details of temperature and rainfall in 1956 for the locality in which the experiment was carried out, are given in Table 48.

It will be seen that, from March to October 1956, monthly temperatures were not greatly different from the seasonal normals. Rainfall, on the other hand, showed considerable fluctuations from the monthly averages.

In 1955 felling was carried out in mid-May; in 1956, in mid-March. The stacks in 1955 were exposed to higher (5 to 12°F.) mean air temperatures partly on account of this difference in time of felling, but also because the spring and summer of 1955 were generally warmer than in 1956.

During the first four to five weeks of the experiment in 1955 the timber was exposed to almost continuous rain, followed by an abnormally dry spell that lasted most of the summer. Rainfall in 1956, although showing considerable monthly fluctuations, was more evenly distributed over the period of the experiment.

The Loss of Weight in 1956

The rate at which the various stacks lost weight were calculated from the field data. The total loss in weight per stack, up to the middle of each month, in 1956 is given in Table 49 as a percentage of fresh-felled weight.

In 1955, over the whole experiment, the top layers lost more weight than the bottom layers both in wet and dry spells. No such regularity of behaviour was evident in the 1956 results.

Except for sycamore, the stacks in the forest clearings lost more weight than those under forest canopy. This is in line with general experience that over a period drying conditions in the open are usually better than those inside the forest, in spite of the protection from direct rainfall which the forest canopy provides. (Timber stacked on the edge of a clearing or ride just under the canopy often dries most rapidly of all.)

Comparison of 1956 and 1955 Results—Stacks under Forest Canopy

In the first month after felling in 1956, stacks had lost up to five per cent of their fresh-felled weights. A similar result was obtained in 1955, although then the rainfall was much greater than in 1956.

Two months after felling in 1956, oak, ash and elm had still not lost more than 5 per cent of their original weight; beech, birch, sweet chestnut and sycamore had lost 5 to 8 per cent. In 1955, two months after felling, ash and sycamore had lost less than 5 per cent of their fresh felled weight and all other species 5 to 9 per cent.

The somewhat greater losses in weight in 1955 are not surprising, in view of the almost complete lack of any rainfall in the fifth to eighth week after felling in that year.

By mid-October 1956, i.e. seven months after felling, the losses in weight were: oak 7 per cent, ash 4 per cent, birch 11 per cent; beech, sweet chestnut, sycamore and elm 14 to 22 per cent.

Losses in weight at the end of September 1955, i.e. only four and a half months after felling, were: ash 8 per cent and all other species 14 to 21 per cent. The generally greater losses in weight in 1955, in an appreciably shorter time, were probably the result of the abnormally low rainfall of only 2·01 inches (total) for July, August and September of that year.

Conclusions

The combined results of the two years' work indicate that small-sized unpeeled hardwoods felled in the spring and stacked in open piles in the forest may:

(1) Lose up to 5 per cent, but probably not more, of their fresh-felled weight one month after felling.

(2) Lose 5 to 10 per cent of their fresh-felled weight two months after felling. Of the species tested ash is an exception and is likely to lose less than 5 per cent.

(3) Lose up to 20 per cent of their fresh-felled weight by the end of the summer.

If stacked in open piles in forest clearings, greater losses in weight may be expected, especially after the first few months.

Table 47

Moisture Content as a Percentage of Oven-dry Weight

Species	Stacks under forest canopy		Stacks in forest clearings	
	On day of felling (March, 1956)	At mid October 1956	On day of felling (March, 1956)	At mid October 1956
Oak	72	59	71	52
Ash	42	37	52	44
Beech	80	47	77	43
Birch	69	51	76	53
Sweet Chestnut	90	62	90	57
Sycamore ..	84	44	79	42
Elm	80	54	66	39

Table 48

Monthly Air Temperatures and Rainfall
Parkend, March to October 1956

Month 1956	(A) Monthly mean air temperature	(B) Average monthly mean air temperature	A as % of B	(C) Monthly rainfall	(D) Average monthly rainfall	C as % of D
March	42·7	42·0	101·7	0·92	2·8	32·9
April	44·1	45·8	96·3	2·18	2·4	90·8
May..	51·6	51·7	99·8	0·90	2·5	36·0
June..	55·9	57·1	97·9	3·19	2·8	113·9
July	61·5	60·1	102·3	1·10	2·9	37·9
August	57·3	59·3	96·6	3·45	3·7	93·2
September	58·3	55·5	105·0	4·81	2·7	178·1
October	49·3	49·3	100·0	1·64	4·2	39·0

Table 49

Total Loss in Weight as a Percentage of Fresh-felled Weight
(Felling and Stacking at Mid-March)

Column A: *Stacks under forest canopy*
Column B: *Stacks in forest clearings*

Month*	Oak		Ash		Beech		Birch		Sweet Chestnut		Sycamore		Elm	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
April	2	3	1	1	3	4	3	3	4	5	5	5	2	4
May..	3	5	1	2	7	7	5	6	8	8	8	9	4	7
June..	4	7	2	2	10	10	6	8	10	11	12	13	6	11
July	5	8	2	3	13	13	8	9	12	13	15	16	9	13
August	6	9	3	4	15	15	9	11	13	15	17	19	11	15
September	7	10	3	5	17	18	10	12	14	17	20	22	13	17
October	7	11	4	5	18	20	11	13	14	18	22	24	15	18

* Total loss of weight up to Mid-April, Mid-May, etc.

FIRST REPORT ON AN INVESTIGATION BEGUN IN 1935 INTO THREE RACES OF EUROPEAN LARCH

By M. V. EDWARDS

232.12

The larch provenance experiment of 1931–32, described in the *Report on Forest Research* for 1956, did not include the Sudeten larch, and it was thought necessary to undertake a second experiment in which this important provenance or variety was included.

The seed of three provenances representative of Alpine larch, Sudeten larch and Scottish larch was sown by J. A. B. Macdonald in 1933. Seed from the Münsterthal in the eastern high Alps where Switzerland adjoins Austria was used, as in the older experiment. (Addendum 1, page 182.) The Sudeten larch was obtained from Silesia, and though it was then sometimes referred to as *L. decidua* var. *silesiaca*, *vide* Dallimore and Jackson (1948, pages 349–50) it was in fact named Sudeten larch by the supplier, and the habit and appearance of the plants has since been found similar to others of guaranteed Sudeten parentage, i.e. *L. decidua* var. *sudetica* Domin (Rübner, 1943). It has, however, passed one generation in Silesia, probably away from its native habitat; and either from this cause or perhaps from cross-pollination, the seed was not a perfect representative of Sudeten larch. In other plots from the same seed, not in these experiments, a few individuals resembling the hybrid between *L. decidua* and *L. leptolepis* have been found, indicating some impurity of strain. Seed from Darnaway Estate in Moray was chosen as the Scottish representative, typical of good larch grown in Scotland, but the stand from which it was obtained is not recorded and this sample is not necessarily typical of all Darnaway larch. Differences in the cone characteristics of the various provenances are illustrated in Fig. 9.

Summary of the Nursery Stage

As in the earlier experiment, the plants were raised in several nurseries to ensure that differences in early treatment were brought to account. Four of the six nurseries used before were selected. The sowing procedures were the same, except that equal quantities of seed were sown in each plot without making any adjustment for impurities mixed with the seed, different seed sizes, or capacities for germination.

Germination

At all nurseries the seed was sown on May 2nd, 1933. At Ratagan nursery the Darnaway seed germinated first and was followed by both the other provenances three days later. At Altonside nursery, all started on the same day, but the germination of the Darnaway seed proceeded fastest; while at Inchnacardoch no differences were reported until the end of the germination period, which was first reached by the Darnaway provenance.

Production and Growth of Seedlings

The seed had been drill-sown at 42 square yards per lb. and in all nurseries the production was highest for Darnaway and lowest for Münsterthal seed (Table 50). This was simply a reflection of the numbers of viable seed sown.

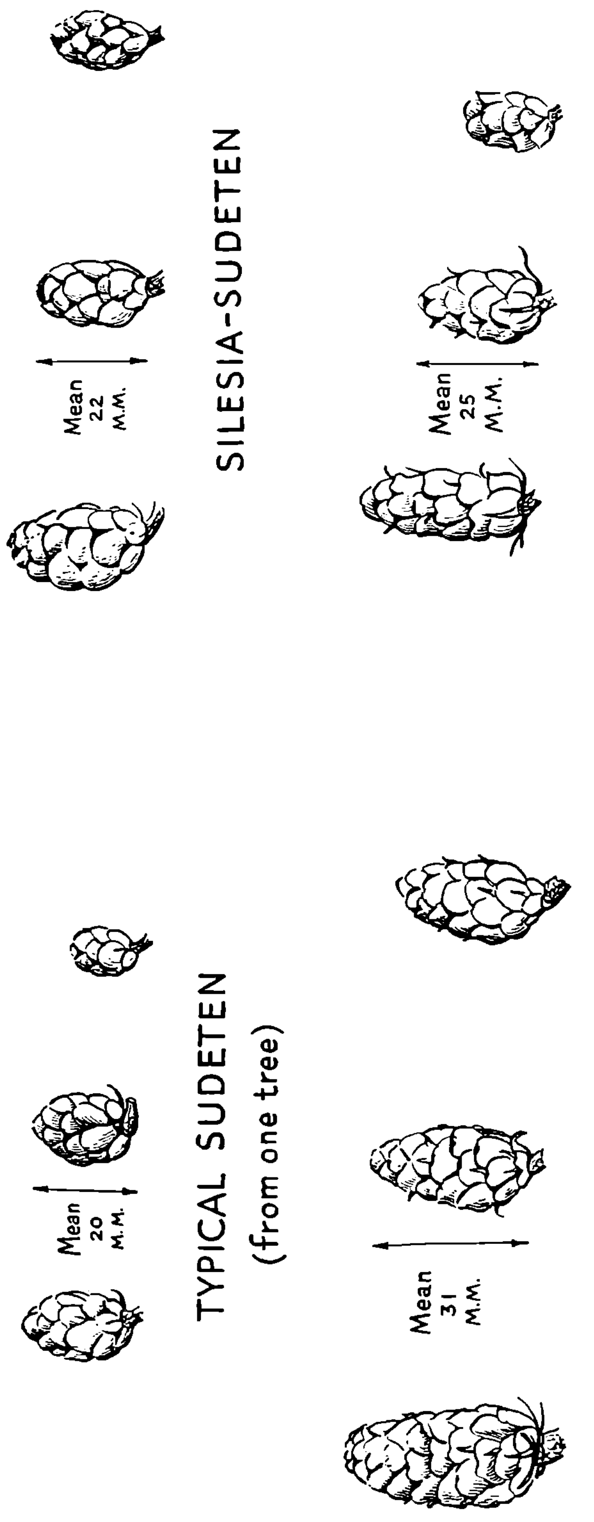


FIG. 9. Representative Cones of Four Provenances of European Larch, showing Range of Size and Form.

The different densities of plants which resulted make comparison of other characteristics difficult. The mean height of the plants of the Münsterthal and Sudeten provenances was not significantly different (Table 51) but the height of the Darnaway provenance was significantly lower than the others in all nurseries. Whether this is an inherent characteristic, or whether it is the result of the higher sowing density is, unknown. The Darnaway provenance also produced a lower percentage of usable plants, i.e. plants of two inches in height and over (Table 52). Nevertheless, in terms of production of usable plants per pound of seed, the Darnaway provenance stood highest (Table 53).

The different methods of assessing the results are of interest, especially in comparison with those used in the previous experiment. It is clear that it is necessary to sow the different lots of seed at rates adjusted to provide equal numbers of viable seed per unit area of seedbed (implying accurate testing of the seed) and to base comparisons on estimates of the total production of all plants and the mean height at the end of the seedbed stage. As a simple approximation, the *percentage* of seedlings which are usable is a useful figure in normal practice (Jeffers, 1955) and better than calculations of the out-turn of usable seedlings *per pound of seed sown.*

Transplanting

The seedlings, with the exception of plants under two inches and a few other culls, were lined out in the same nurseries in March 1934.

After one season they were planted out in two forests. No records were kept of the transplant stage, but it was recorded that the heights of the plants planted in one experiment (Drummond Hill) were as follows:

Provenance (mean of all nurseries)	inches	*Nursery* (mean of all provenances)	inches
Münsterthal	6·2	Ratagan ..	3·3
Sudeten ..	6·5	Altonside ..	5·0
Darnaway ..	6·2	Inchnacardoch ..	7·0
		Royal Botanic Garden	10·0

At this stage it is evident that the size of the plants depended far more on the nursery of origin than on the provenance of the seed.

Early Growth in the Forest

Experimental plantations were made in the autumn of 1934 at Drummond Hill and Clashindarroch forests, as in the case of the previous experiment, though in other parts of these forests. No suitable ground was available at Lael Forest, and no suitable alternative for that third site was found. The plants were notched without any special method of ground preparation. (See Addendum 2, page 183.)

The experiment was designed as a 3 × 3 Latin Square, each provenance main plot being split into four for the plants from the different nurseries. These subplots consisted of 36 plants spaced four feet apart with a blank line between plots, the main plots thus comprising 144 plants and covering 0·062 or about $\frac{1}{16}$th acre. Though this design has given precise results for the differences between the nurseries of origin, the error must be unusually small, or the differences between the provenances very large, before they achieve significance. The fact that some of the data are shown as "not significant" sometimes implies that the statistical design is inadequate, rather than that the differences are unimportant.

At the end of the first summer, the failures were 3 per cent at Clashindarroch, and 25 per cent at Drummond Hill. In neither case were the failures related to either the seed provenance or the nurseries of origin.

At the end of the second season, additional casualties were few and the only significant difference was at Clashindarroch where plants from the Royal Botanic Garden survived significantly better than those from other nurseries (Table 54). These plants were outstandingly the largest at the time of planting. The great difference in growth between the two forests must first be noted (Table 55), but within these sites the only significant difference in mean height between provenances was at Drummond Hill where the tallest (Sudeten) was significantly bigger than the shortest (Münsterthal). In this case the Sudeten plants had been the tallest when planted. Differences in height between plants from different nurseries were highly significant in both experiments, following the differences at the start.

By the seventh year it was obvious at Clashindarroch, though not at Drummond Hill, that the Münsterthal provenance was not growing so fast as the others, and from that time onwards the differences became still more marked.

Phenology

In the Nurseries

During the first autumn in the seed beds the plants from Darnaway seed retained their needles almost completely at Altonside and Inchnacardoch nurseries. At the latter place the plants from Münsterthal seed lost more needles than either of the other provenances. No other differences were reported.

Records of the state of flushing were made between March 24th and 28th in the following spring, except at the Royal Botanic Garden. The Münsterthal provenance was more advanced than the others at Ratagan and Inchnacardoch nurseries, but at Altonside, the Darnaway provenance commenced to grow much earlier than the others and the Sudeten plants were the last to move.

The First Seasons in the Forest

The plots were examined four times during the first spring after planting. The results were similar at both Drummond Hill and Clashindarroch, the Münsterthal provenance being the first to start flushing in March and the last to reach the final stage in June. The Darnaway provenance was the last to start at Drummond Hill and the second to start at Clashindarroch, but in both centres it soon caught up and completed flushing first. The stage of flushing was assessed in the same five standard classes as in the 1931–32 experiments, and the classification was made in both forests by J. Farquhar, so that the results are consistent. Further evidence that trees from the Münsterthal flush earlier in Scotland has therefore been obtained, and there is some reason to think that plots of Darnaway origin start later and finish first.

During the following autumn the state of leaf fall was recorded periodically. At Drummond Hill the needles had commenced to turn yellow by November 4th in all provenances, and defoliation was complete by December 2nd. Within this period differences were small, but it was recorded that defoliation was well advanced in all the Sudeten plots, only three out of the four Darnaway and in only one of the Münsterthal plots. No differences at all were recorded at Clashindarroch when examinations were made on two occasions in November.

Results After Approximately Twenty Years

Height

Measurements were made in 1953 at Drummond Hill Forest and in 1957 at Clashindarroch, when the trees were 18 and 22 years old respectively (Table 56). It will be seen that at Clashindarroch the trees were not as tall at 22 years of age as they had been at Drummond Hill at 11 years. In both forests the Münsterthal provenance was much shorter than the other two, though the differences were only statistically significant at Clashindarroch. The Sudeten provenance was the tallest at both places, but only by about one foot at Drummond Hill and three feet at Clashindarroch, and the latter difference was not quite large enough to prove significant. These results confirm the data from the previous experiment of 1931–32, and show that the differences in growth consequent upon the provenance of larch seed are greater on the sites which are less well suited to the species.

In the assessments at Drummond Hill, which were made a season after the first thinning, a particular point of interest came to notice. The measurements of the height of the tallest trees in the plots, corresponding to 128 per acre and thus nearly equivalent to top height, showed small differences between provenances. Though the figure for Münsterthal was in fact 90 per cent of that for the Sudeten provenance, to the eye the height growth of the Münsterthal trees was greatly inferior, with relatively small trees suffering from dieback and canker, as will be explained below. The regularity of the crop is best shown by the coefficient of variation of the height of the trees within each plot, and the mean for each provenance is indicated in Table 57. (The coefficient of variation is the standard deviation of the mean of the height of the trees in a plot, expressed as a percentage of the mean height.) This figure is highest in both forests for the Münsterthal provenance. The figures for the two forests are not directly comparable, as the data from Drummond Hill were obtained after a thinning which had already removed part of the variation, but the reduction in irregularity caused by thinning is indicated.

Crop Data

Data are only available for the experiment at Drummond Hill, as the one at Clashindarroch has not yet been thinned. Thinnings are being conducted in a normal silvicultural manner to raise the best crops, that is by removing inferior trees and giving the remaining better ones approximately equal growing space. This resulted in about the same *spacing index* for each provenance (i.e. mean space calculated as a percentage of mean height)—Table 58. The Darnaway provenance shows the greatest total production to date as well as the largest main crop basal area, but it is early yet to suggest that this provenance is in fact more productive than the other two, and further measurements to produce growth curves over longer periods must be awaited.

Differences due to Nursery Treatment

By the eleventh year, when the mean height of trees from all nurseries was about 13 feet at Drummond Hill and 7 feet at Clashindarroch, the difference between plants from the best and worst nurseries was only about 10 per cent and 18 per cent respectively at the two forests. It may be noted that the differences at the start of this experiment were unusually large.

No subsequent data are available from Drummond Hill, as after thinning the sub-plots were not measured separately. At Clashindarroch, at 22 years of age when the trees were about 14 feet high, the plants from Ratagan were still the shortest and those from the Royal Botanic Garden the tallest, though the differences between them were reduced to about 10 per cent. Again, as in the previous experiment, there is evidence of the importance of differences in the size of nursery stock, especially on the more difficult site. These are distinguishable, as well as the differences due to provenance, for over 20 years, or until the first thinning.

Stem Form

Drummond Hill

In 1958, after the second thinning had been carried out, the form of the stem of the dominant and co-dominant trees was classified visually by the standard system in use in sample plots. (Macdonald, 1931.) Only two Class I stems were found in the experiment and these were both of Münsterthal provenance. On the average for all replications, 92 per cent of the Darnaway stems, 78 per cent of the Münsterthal and 72 per cent of the Sudeten provenance, were placed in Class I or II.

Clashindarroch Forest

A similar classification was made in 1957 before any thinning had been done. On the average 13 per cent of the Darnaway dominants and co-dominants were placed in stem class I, as compared to $1\frac{1}{4}$ and 1 per cent respectively for the Sudeten and Münsterthal provenances. The percentages of stem class I and II stems combined were: Sudeten 70 per cent, Darnaway 62 per cent and Münsterthal 47 per cent. The majority of the Sudeten stems were placed in Class II because of their wavy form, which is characteristic of it in this and other experiments. This defect is found mainly on stems under about three inches in diameter and it appears to become of lesser importance as the crop ages.

Both experiments thus show the general superiority of the Darnaway provenance. There are also good stems in both other provenances. The Class III stems, which are particularly numerous in the Münsterthal provenance on the severe die-back site, are gradually being removed in thinnings. It seems likely therefore, at least at Drummond Hill, that the final differences in stem form between the provenances may not be of great importance.

Resistance to Exposure

Although the experiment at Drummond Hill lies in a valley and is not severely exposed, it is on the edge of the forest and it has suffered from wind blowing down the valley in late spring. In June 1949 the needles on the south-west side of trees of Sudeten provenance turned brown, while trees of all other provenances in the experiment and also in the collection of plots of different provenances adjoining the experiment were unaffected. This effect was noticed after a period of strong winds from the south-west, probably associated with low temperatures. A similar browning of the needles was also recorded in April 1956. It is likely that permanent damage to the trees was caused, as at both Drummond Hill and

Clashindarroch, exposed trees, particularly of Sudeten provenance, tend to lean away from the south-west, and also to lose their branches on the south-west side. Both experiments are sheltered from the north and east by higher ground.

At Clashindarroch, damage was done in an ice-storm in December 1957 and some trees were broken off near the base. This form of damage only occurred in the Sudeten plots.

Larch Die-back

Drummond Hill Forest

Larch die-back has occurred in several parts of Drummond Hill forest, but this experiment was free of it until 1949, when signs of die-back were noticed in the plot of Münsterthal provenance at the south-east corner of the experiment. In 1952, following the assessments of top and mean height and the comparisons of crop regularity that these led to, it was evident that die-back in the Münsterthal provenance was seriously affecting the crop. However, in all plots there was a high proportion of trees which remained unaffected and it seems probable that after a second thinning most of the damaged trees will have been removed.

Stem cankers affected the trees of all provenances, and were counted in 1953 (Table 61) on all stems left after the first thinning, which had removed many of the most affected trees. Though the number of cankers per tree of Münsterthal provenance was much higher than that of the others, the differences did not reach significance.

Clashindarroch Forest

Signs of die-back became serious in older larch plantations adjacent to the experiment about 1937, and by 1942 it was so devastating that a special investigation was undertaken in this forest, as also in other parts of Britain. At that time the experiment was seven years old and the trees had reached about four feet in height, their condition being considered good, but in the following year, July 1943, it was noted that many trees were unhealthy and their leading shoots and side branches were dying back. The trees were attacked by the shoot borer *Argyresthia laevigatella* H.-S., and by *Adelges strobilobius* Kalt. and *A. viridis* Ratz. In July 1944, the condition of the trees was even more serious. They were then ten years old and from 5 to 10 feet tall. They had only grown about 4 to 6 inches in the previous year, and their foliage was estimated at only half the normal, though the attack by *Adelges* was less severe than it had been in 1943. The insect attack had been reported equally severe on trees of all provenances. In the summer of 1945, the insects had virtually disappeared. But the trouble had not ended. It was recorded that the leading shoots of 90 per cent of trees of all provenances had died back and it was noted that the leaders and many of the branches had been affected by cankers which often girdled and thus killed the shoots. These are associated with the fungi *Trichoscyphella* (*Dasyscypha*) *willkommii* and others. Major stem cankers were first reported in 1944, when it was recorded that half of the trees of Münsterthal and Darnaway provenances were affected, but only about 10 per cent of the trees of Sudeten provenance.

After the late frosts in the spring of 1945, an area on the hillside below the experiment down to the Lag Burn, where many trees had been killed, was clearly defined by the browning of the needles of the survivors. In this zone it

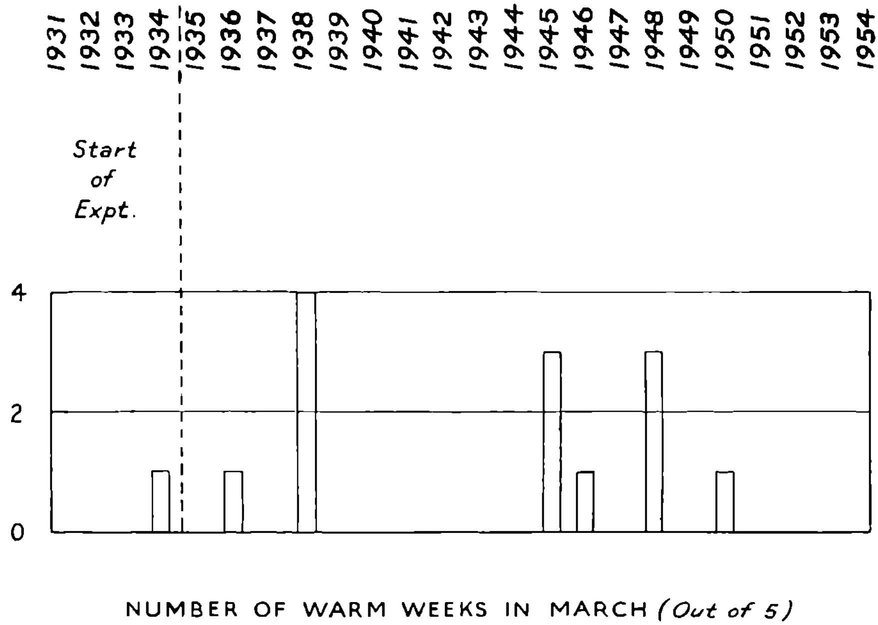


FIG. 10. Warm Weeks in March for the Years 1931 to 1954 inclusive, from records at Craibstone, Aberdeen.

Notes: A "warm week" is one in which the accumulated temperature exceeded one qua ter of the mean monthly accumulated temperature, multiplied by 1½. Thirteen warm weeks occurred in the first 20 years of the experiment's life, 1935–1954, out of a total of 100 weeks falling in March.

The mean accumulated temperature (above 42°F.) for March at Craibstone is 90°. (Shellard, *Monthly averages of Accumulated Temperature*, 1921–50, Meteorological Office, British Climatological Branch Memorandum No. 5.)

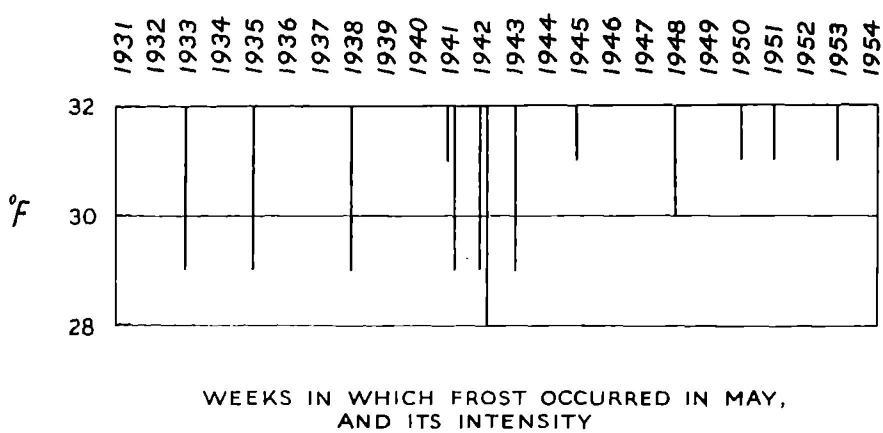


FIG. 11. Diagram showing the number of weeks in each year, from 1931 to 1954 inclusive, in which frosts were recorded at Craibstone in May, and the lowest temperature recorded in each week.

was found that trees had been killed outright without gradual die-back of the shoots. The important part played by frost in the onset of the disease was evident. Figs. 10 and 11 show the unusual number of frosty weeks in May in the years 1941 to 1943, which followed severe late frosts in 1933, 1935 and 1938, and an unusually warm March in 1938, as recorded near Aberdeen; it is possible that these factors accentuated the severity of the die-back. The problem was investigated by Laidlaw (1945a and 1945b), with particular reference to the insect pests, and he concluded that frost and canker were much more important causes of die-back than the insect attack.

In September 1948 detailed assessments were made of both dieback and canker. At this time the mean height of the trees of each provenance was as follows: Münsterthal—5·5 feet, Sudeten—9·7 feet and Darnaway—7·2 feet. A visual score was made on each tree, viz.:

(1) No die-back.
(2) Slight die-back.
(3) Severe die-back.
(4) Dead.

Table 59 shows that the average classification of the trees of Münsterthal provenance was higher than that for the Sudeten and Darnaway provenances. There was also probably some interaction with site factors, the die-back being most serious towards the south-eastern corner of the experiment. The number of dead trees was greatest for the Münsterthal and least for the Darnaway provenance.

The cankers on each tree were assessed by visual scoring in five classes viz.:

(1) No cankers.
(2) One or two slight cankers.
(3) Two or three cankers.
(4) Badly cankered (over four).
(5) Whole tree cankered.

The results (Table 60) showed no significant differences, but as in the case of die-back there was some interaction with site. Cankering was most severe at the lower end of the experiment. These figures contradict the earlier observation that few of the Sudeten trees were affected by canker. In 1957, at 22 years of age, another assessment was made. In this case the number of stem cankers was counted. Only those larger than a florin, up to a height of 10 feet from the ground and on the dominant and co-dominant trees, were included. These counts gave the mean number of cankers per tree as follows: Münsterthal—4·0, Sudeten—1·8 and Darnaway—3·4.

Assessment of the cankering of different parts of the tree at different ages thus gives variable results. Distinction needs to be made between multiple cankers on branches as well as stems, before or at the time of canopy formation, which are closely related to the death of trees; and stem cankers which do not heal and which affect the quality of the timber. At the earlier stages more precise methods of assessment were evidently necessary, but the method of assessment adopted in the later stages for the stems appears to be adequate.

In 1949 a survey was made in all the parts of Clashindarroch forest where European larch had suffered from die-back. Out of 880 acres planted between 1930–38, 263 acres (30 per cent) had grown satisfactorily, 43 acres (5 per cent) has been completely killed and replanted with other species and 574 acres (65 per cent) has been attacked by die-back and affected sufficiently to cause the death of some trees. This area was reclassified thus:

	Acres	Per cent
Up to one-quarter of the trees dead	92	16
One-quarter to one-half of the trees dead ..	223	39
One-half to three-quarters of the trees dead ..	171	30
Over three-quarters of the trees dead	88	15
	574	100

It was recorded that die-back increased in severity from the top of slopes down to valley bottoms and that many sickly trees later made good growth, especially in the leaders. (East Conservancy, Scotland, Report, 1949.) An investigation into the source of the seed used for forming these plantations was made, and it was found that most of it had been gathered in Scotland, to the extent of 78 per cent, and that Switzerland had provided 20 per cent and Silesia and Austria 2 per cent (Gillespie, 1944).

Seed Provenance, Die-back and Canker

The first record of "larch disease" in Britain stated "Previous to the year 1795, a blight (occasioned by an insect) affected the larch and of those in low situations many died. At that time the frost was very severe . . . in spring". (Atholl, 1832.) Thus it had been shown over a century and a half ago that attack by insects is sometimes the herald of die-back, and that there is also evidence of association with frost. In 1880 Hartig attributed die-back and canker to the fungus *Dasyscypha willkommii.* Münch (1936) surveyed the problem and found in Germany that the stands which were attacked had been raised from seed of Tirolese origin, and that larch from Sudeten seed was immune, confirming the work of earlier writers on frost and seed provenance. The researches of Day and Peace (1934) illustrated and emphasised the importance of frost and its mode of action, and Day (1951) confirmed its importance and interaction with seed provenance by laboratory freezing trials.

These experiments have re-enacted the history of the disease as recorded in the earliest larch crops planted in Scotland. The experiments replicate provenances in different localities and thus illustrate the interactions between the four main factors involved; insects, frost, fungi and seed provenance. Even at Clashindarroch, where die-back was the most serious, the insect attack was held to be a relatively minor factor, although no doubt it had some effect by reducing the vigour of the trees. The remaining three factors are the important ones. No attempts have been made in these experiments to disentangle the effects of frost and fungi as causes of die-back and canker, but no evidence has been obtained that fungi are a cause apart from frost. The extreme severity of die-back in the valleys liable to late frosts adjacent to the Clashindarroch experiment leaves little doubt that frost is the most potent cause. As far as is known no provenance is more susceptible to die-back than that from Münsterthal, though plants of other high-elevation Alpine origins also suffer severe die-back, e.g. French Alps (2,800 feet) (Edwards, 1942), and there are indications in the younger international larch provenance experiment of 1944 which is now entering the critical stage that Lötschenthal, Wallis (4,900 feet) and Untervaz, Graubünden (1,400–2,100 feet) are also very susceptible. (Data unpublished.) The experiment of

1931–32, already described, shows that in the most favourable locality, considered from the point of view of both soil fertility and absence of frost (Lael Forest), even Münsterthal larch does not suffer die-back. On such sites it may be presumed that the likelihood of die-back occurring in any provenance is remote. At Drummond Hill some crops of Münsterthal provenance, both within and outwith experiments, have grown well and escaped die-back; while other crops, as in this experiment, have suffered at the time of canopy formation. This forest is evidently marginal for Münsterthal and similar provenances. At Clashindarroch, the poorest site in these experiments from all points of view (though not necessarily the poorest site on which larch has been grown successfully in north eastern Scotland) no provenance yet tested has resisted die-back completely.

It follows that, provided the locality factors are otherwise suitable, any provenance can be used in places free from frost, but where frost it to be feared, then the choice is restricted. In practice, the risk of frost is such that it is considered unwise to use any seed of high Alpine provenance in Britain. True Sudeten and certain Scottish provenances appear to resist die-back and to grow satisfactorily even if exposed to severe frosts.

A provenance cannot always be considered to be a homogeneous population and important differences between individuals within a provenance have manifested themselves. Thus at Clashindarroch, in the Sudeten larch, there appear to be differences in the resistance to canker of the dominant and the other trees, as has already been described. It is likely that the contradictions about the susceptibility of a provenance to die-back or canker which have arisen are caused by differences of this nature. Again it has already been shown that the crops of Münsterthal provenance are more irregular than others, and that is due, not so much to the absence of a proportion of vigorous trees, as to the presence of a high proportion of poor trees. There is little doubt that the latter are the individuals seriously affected by die-back, and that the vigorous trees are those which are relatively resistant.

In his address to the British Association in Dundee in 1947, MacDonald (1949) suggested that the reputation of Scottish larch for resisting die-back rests on plants grown from collections of seed from oldish trees which had been exposed in their youth to the die-back, had survived it and had transmitted the resistance to their progeny. This selective process is evidently now in progress in all provenances in these experiments, and the most important difference between the provenances is the proportion of resistant trees, which is low in the Münsterthal but high in both the other provenances. The resistant Darnaway larch is not morphologically similar to larch from the Sudetenland or other eastern part of its distribution. It bears more resemblance to the Tirol larch from the eastern Alps, and in fact that is traditionally the source of the Scottish larch in Atholl. As already shown, much of that larch went through a die-back phase and seed could only have been collected from resistant individuals in such stands. But, as is evident from the survey of die-back made at Clashindarroch, Scottish larch seed does not always produce resistant crops, and in such cases perhaps the parent stands had not been exposed to conditions likely to cause die-back, so that no elimination of susceptible individuals could have taken place.

Within the Scottish provenances, one from Darnaway has been proved satisfactory on a marginal and extremely severely testing site. There is unfortunately no way of determining whether seed collected in Scotland comes from stands of a provenance resistant to die-back, or which have suffered from die-back and may be composed of resistant individuals, unless history records the fact. If plantations of larch are to be made on sites which may be frosty, and the risk of die-back reduced, it is necessary to use either Scottish larch of proved resistance on an equally frosty site or Sudeten larch. There is evidence that other eastern provenances, such as Polish or Tatra larch, are equally resistant, but these have not yet been adequately tested experimentally.

Recovery from larch die-back in these experiments is being effected by the gradual elimination of susceptible trees, whose place in the canopy is taken by more resistant individuals. If the proportion of trees killed or severely damaged is large, a complete crop cannot be obtained, as has happened outside the experiment at Clashindarroch, but if the proportion is small, e.g. Drummond Hill, their place is sooner or later taken by others. Under such conditions the loss occasioned by the use of an unsuitable provenance is restricted to the period of early thinnings, and after that stage crops of equal health and vigour may be obtained.

Summary

The nursery and early forest stages of a provenance experiment with Alpine (Münsterthal, Switzerland), Sudeten (Silesia) and Scottish (Darnaway) larch are described. Observations at the nursery stage suggested that the differences in size of seedlings or transplants produced, as between different *nurseries*, were greater than any inherent differences between the three *provenances*. On the average for all four nurseries, the seedlings of Münsterthal and Sudeten provenance were significantly taller than those from Darnaway, but for the Darnaway provenance the number of seedlings raised per square foot was the largest, due to a higher percentage of viable seed, and the consequent crowding may have depressed height growth.

Plantations were made in two different forests, and growth was much faster at one of them, where the trees were taller at 11 years than in the other forest, a marginal site, at 22 years. Differences in height consequent on differences due to nursery of origin persisted for 22 years at the slow-growing site and until about the time of the first thinning (17 years) at the faster-growing site. It became evident about the seventh year that the Münsterthal provenance was growing more slowly than the other two and the difference was significant by the twenty-second year at the marginal site, but smaller at the better site. Differences between individual trees were greatest in the Münsterthal provenance, which produced less uniform crops than the Sudeten or Darnaway provenances.

Phenological data were inconclusive, but indicated that Münsterthal plants often flushed earlier in the spring than Sudeten or Darnaway plants, the last-named sometimes completing flushing first.

The stem form of the Darnaway provenance was the best, but thinning is gradually reducing the differences.

Both experiments were subject to die-back during the canopy-forming stage, but only the Münsterthal provenance suffered at the better site, and it suffered the worst at the marginal site. Insect attack accompanied the die-back, but was not considered as important a cause as frost and the fungus *Trichoscyphella* (*Dasyscypha willkommii*).

Differences within provenances were of importance, the Münsterthal plots containing a proportion of resistant trees which grew well in spite of the suscep-

tibility to die-back of most, whereas the Sudeten and Darnaway plots were more uniformly resistant. Stem cankers were found on trees of all provenances, but there were few, in comparison with other provenances, on the dominant trees of Sudeten origin.

It is concluded that Alpine provenances do not suffer from die-back on the most favourable sites, but the risk of frost is too great to permit of their use, and that Sudeten and certain tested Scottish provenances are resistant under fairly severe conditions, where they are able to produce satisfactory crops.

It appears likely that after several thinnings the differences between crops of different provenance at the better site will be reduced to unimportance, but this is not likely to occur, as far as can be seen at present, at the marginal site where the differences are much greater.

REFERENCES

ATHOLL, DUKE OF, 1832. Account of the larch plantations on the estates of Atholl and Dunkeld, executed by the late John, Duke of Atholl. *Trans. Highland Soc. of Scotland*, 9, pages 165–219.

DALLIMORE, W. and JACKSON, A. B., 1948. *A Handbook of Coniferae*. 3rd edn. London. E. Arnold.

DAY, W. R., 1931. Relationship between frost damage and larch canker. *Forestry*, 5(1), 41–56. illus.

DAY, W. R. and PEACE, T. R., 1934. *Experimental production and the diagnosis of frost injury on forest trees*. Oxf. For. Mem. No. 16.

EAST CONSERVANCY SCOTLAND, REPORT, 1949. Census of Die-back in European Larch on Clashindarroch. (Unpublished.)

EDWARDS, M. V., 1952. Provenance Studies. *Rep. For. Res., For. Comm.* 1951, 38–39.

EDWARDS, M. V., 1957. Third report on an investigation of 1931–32 into various races of European larch. *Rep. For. Res., For. Comm.* 1956, 142–154.

GILLESPIE, I., 1944. Report on Clashindarroch Forest. Appendix 2. (Forming Appendix I to the Forest History, 1951.) (Unpublished.)

GLENTWORTH, R., 1954. *Soils of the Country around Banff, Huntly and Turriff.* Mem. Soil Survey of Gt. Britain. Sheets 86 and 96. H.M.S.O.

JEFFERS, J. N. R., 1955. Relationship between the percentage of usable conifer seedlings and the mean height of seedlings as assessed at stocktaking. *Rep. For. Res., For. Comm.* 1954, 101–106.

LAIDLAW, W. B. R., 1945a. Report on European larch die-back investigation. (Unpublished. Silv. N., I. File 48.)

LAIDLAW, W. B. R., 1945b. Die-back of European larch at Clashindarroch. Report to Advisory Committee on Forest Research. (Unpublished.)

MACDONALD, J., 1931. Sample plot methods in Great Britain. *Emp. For. J.* 10, pages 243–4.

MACDONALD, J., 1949. Notes on the die-back of European larch. *J. For. Comm.* 20, 192–8. (Circulated departmentally.)

MUIR, A. and FRASER, G. K., 1940. Soils and vegetation of the Bin and Clashindarroch Forests. *Trans. Roy. Soc. Edinburgh*, 60(1), 233–341.

MÜNCH, E., 1936. Das Lärchensterben. *Forstwiss. Cbl.* 8, 469–94, 537–62, 581–90 and 641–71. Review by W. R. Day in *Forestry*, 1937, 11(2), 109–116.

RÜBNER, K., 1943. Das Areal der Sudeten Lärche. *Tharandter Forstliches Jahrbuch* 94 (1–3), 1–99.

RÜBNER, K. and SVOBODA, P., 1944. Researches on larch cones of different provenances. *Intersylva* 2, 121–146.

Table 50

Number of Seedlings per Square Foot

Age 1 year

Nursery	Münsterthal Switzerland	Sudeten Silesia	Darnaway Moray	Mean
Ratagan (Expt. No. 1, P. 33) ..	28	44	73	48
Altonside (Expt. No. 4, P. 33) ..	31	31	63	41
Inchnacardoch (i.e. Auchterawe) (1, P. 33)	22	51	80	51
Royal Botanic Garden (i.e. Inverleith) (3, P. 33)	22	56	86	55
Mean	26	46	76	—

Table 51

Mean Height of Seedlings

Age 1 year (inches)

Nursery	Münsterthal Switzerland	Sudeten Silesia	Darnaway Moray	Mean
Ratagan	1·3	1·2	1·1	1·2
S.E.		±0·02 Significant at 1% level		
Altonside ..	2·6	2·8	2·2	2·6
S.E.		±0·17 Significant at 5% level		
Inchnacardoch ..	1·9	2·0	1·9	1·9
S.E.		±0·06 Significant at 1% level		
Royal Botanic Garden ..	3·8	4·0	3·4	3·7
S.E.		±0·13 Significant at 5% level		
Mean	2·4	2·5	2·1	—
S.E.		±0·07 Significant at 5% level		
Critical difference, 5% level, 0·3				

Note: The S.E. of the means for the different nurseries is 0·08 and the difference between nursery means is very highly significant (0·1% level). Critical differences: 5% level 0·3, 1% level 0·4.

Table 52

Percentage of Seedlings 2 inches Tall and Over

Age 1 year

Nursery	Münsterthal Switzerland	Sudeten Silesia	Darnaway Moray	Mean
Ratagan	14	11	5	10
Altonside	64	74	50	63
Inchnacardoch	41	48	41	43
Royal Botanic Garden	89	88	62	80
Mean	52	55	40	—

Table 53

Production of Seedlings 2 inches Tall and Over

Thousands per pound of seed

Nursery	Münsterthal Switzerland	Sudeten Silesia	Darnaway Moray	Mean
Ratagan	1·5	1·9	1·4	1·6
Altonside	7·5	8·8	12·3	9·5
Inchnacardoch	3·5	9·4	12·8	8·6
Royal Botanic Garden	7·6	19·1	26·5	17·7
Mean	5·0	9·8	13·2	—

Table 54

Survival after Second Summer after Planting, October 1936

Per cent

<table>
<tr><th rowspan="2">Nursery</th><th colspan="4">Drummond Hill</th><th colspan="4">Clashindarroch</th></tr>
<tr><th>Mün-sterthal</th><th>Sudeten</th><th>Darna-way</th><th>Mean</th><th>Mün-sterthal</th><th>Sudeten</th><th>Darna-way</th><th>Mean</th></tr>
<tr><td>Ratagan ..</td><td>76</td><td>64</td><td>86</td><td>75</td><td>93</td><td>96</td><td>97</td><td>95</td></tr>
<tr><td>Altonside ..</td><td>55</td><td>60</td><td>73</td><td>63</td><td>92</td><td>93</td><td>96</td><td>94</td></tr>
<tr><td>Inchnacardoch</td><td>82</td><td>74</td><td>80</td><td>78</td><td>90</td><td>95</td><td>96</td><td>94</td></tr>
<tr><td>Royal Botanic Garden ..</td><td>89</td><td>68</td><td>75</td><td>77</td><td>97</td><td>100</td><td>98</td><td>98*</td></tr>
<tr><td>Mean ..</td><td>75</td><td>66</td><td>78</td><td>73</td><td>93</td><td>96</td><td>97</td><td>96</td></tr>
<tr><td></td><td colspan="4">Differences not significant, on basis of angular transformation.</td><td colspan="4">* Significantly higher than other nurseries, on basis of angular transformation.</td></tr>
</table>

Table 55

Height after Second Summer after Planting, October 1936 Inches

Nursery	Drummond Hill				Clashindarroch			
	Münsterthal	Sudeten	Darnaway	Mean	Münsterthal	Sudeten	Darnaway	Mean
Ratagan ..	14·7	18·3	16·8	16·6	8·1	8·9	11·4	9·5
Altonside ..	14·8	19·3	16·8	17·0	8·8	9·7	9·1	9·2
Inchnacardoch	18·3	23·5	20·2	20·7	13·0	14·3	13·2	13·5
Royal Botanic Garden ..	26·3	32·0	31·0	29·8	18·9	22·2	18·2	19·8
Mean ..	18·5	23·3	21·2	21·0	12·2	13·8	13·0	13·0
Standard errors: Of provenance means			±0·51	of nursery means ±0·71	Of provenance means ±0·35		of nursery means 0·52	
Difference necessary for significance at 5%			3·1	2·1	Not significant			1·5
Difference necessary for significance at 1%			—	2·8				2·0

Table 56

Height Growth after 11 Years, and after 18 or 22 Years Feet

Provenance	Drummond Hill			Clashindarroch		
	Age 11 years	Age 18 years		Age 11 years	Age 22 years	
	Top ht.*	Mean ht.	Top ht.*	Top ht.*	Mean ht.	Top ht.*
Münsterthal	14·5	26·5	36·2	5·4	10·4	18·6
Sudeten	19·6	34·7	40·9	8·3	18·2	26·8
Darnaway	17·5	33·7	39·4	6·7	15·1	23·6
Standard error	—	±1·20	±1·21	—	0·56	0·89
Difference for significance 5% ..	—	Not sigt.	Not sigt.	—	3·6	5·4
Nursery						
Ratagan	12·4	Not determined		6·3	13·9	23·2
Altonside	12·2			6·3	14·2	21·8
Inchnacardoch	13·3			6·9	14·6	22·9
Royal Botanic Garden	13·6			7·7	15·5	24·2
Standard error	—	—	—	—	0·31	0·68
Difference for significance 5% ..	—	—	—	—	0·9	Not sigt.

Notes: * Height of two largest trees per sub-plot, or eight per main plot, equivalent to 128 per acre.

The data for Clashindarroch were recorded before thinning.

The 18-year measurements at Drummond Hill were recorded after one thinning.

Table 57

Measurement of Crop Regularity

Coefficient of Variation

Provenance	Drummond Hill		Clashindarroch
	18 years after one thinning	23 years, after two thinnings	22 years, before thinning
Münsterthal ..	22·2	17·9	42·7
Sudeten	13·7	11·1	31·1
Darnaway.. ..	13·4	10·0	32·3

Note: The coefficient of variation is the standard deviation of the mean height, expressed as a percentage of the mean height.

Table 58

Crop Data: Drummond Hill

	Top height (approx.)	No. per plot	No. per acre	Basal area: Spacing index	Main crop sq. ft. per plot	Main crop sq. ft. per acre	Thinnings sq. ft. per plot	Thinnings sq. ft. per acre	Total sq. ft. per plot	Total sq. ft. per acre	Quality class
			First Thinning 17 years								
Münsterthal ..	34	52	(830)	21	4·23	(67)	0·46	(7)	4·69	(74)	Mean II
Sudeten	38	41	(660)	21	4·48	(72)	1·83	(30)	6·31	(100)	Low I
Darnaway ..	37	43	(690)	22	4·27	(68)	2·20	(35)	6·47	(103)	I/II border
			Second Thinning 21 years								
	Top height										
Münsterthal ..	40·9	36	(570)	22	5·31	(85)	1·59	(25)	7·36	(120)	Mean II
Sudeten	45·2	29	(460)	22	4·95	(79)	1·06	(17)	7·84	(125)	Low I
Darnaway ..	44·3	33	(530)	20	5·41	(87)	0·99	(16)	8·60	(140)	I/II border
	±0·95 Not sigt.	—	—	—	±0·197 Not sigt.	—	±0·100 Not sigt.	—	—	—	

Note: Data per acre obtained by multiplying the means of three plots of one-sixteenth acre each, and therefore only approximate.

Table 59

Incidence of Die-back. Clashindarroch
Mean class for all trees. September 1948. Age 14 years*

Provenance	Mean Die-back Class			No. of dead trees
(M) = Münsterthal	2·7	†53·8	S.E. ±0·44	41
(S) = Sudeten	2·3	†48·4		23
(D) = Darnaway	2·4	†49·9		18
Difference necessary for significance at 5% level:		2·7		—

* Trees were classified into four classes, *see* text, p. 173.
† Angular transformation.

Table 60

Incidence of Canker, Clashindarroch
A. Age 14 years. Mean class for all trees in plot. September 1948

	Latin Square			Mean of rows	
	(D) 2·6	(M) 2·6	(S) 2·8	2·7	These differences approach significance
	(M) 2·8	(S) 3·2	(D) 2·8	2·9	
	(S) 3·2	(D) 3·1	(M) 3·5	3·3	
Mean	2·8	2·9	3·1		

B. Age 22 years. Mean No. of stem cankers larger than a florin on the tallest trees. June 1957

	Latin Square			Mean	
	(D) 2·9	(M) 4·9	(S) 2·4	3·4	Differences not significant
	(M) 3·3	(S) 1·0	(D) 3·5	2·6	
	(S) 2·0	(D) 3·8	(M) 3·9	3·2	
Mean	2·7	3·2	3·3		

C. Comparison of Data at 14 and 22 years

Provenance	All trees Canker Class at age 14	Tallest trees No. at age 22
(M) = Münsterthal..	3·0	4·0
(S) = Sudeten ..	3·1	1·8
(D) = Darnaway ..	2·8	3·4

Table 61

Incidence of Cankers—Drummond Hill
Mean No. of cankers per tree up to 10 feet. All trees after first thinning.
January 1953. Age 18 years

Provenance	Mean No. of Cankers
Münsterthal	2·9
Sudeten	0·2
Darnaway	0·7

The differences are not significant.

Addendum 1

Seed Provenance Data

Münsterthal, Switzerland. Supplied by J. J. Roner. Native larch from the woods of Münster, at an altitude of 1,200 metres (3,900 feet) and over. Lat. 46° 35′–38′ N. Long. 10° 20′–27′ E. 1932 crop. Identity No. 33/27. Purity 87·6 per cent. Germination 25 + 1 per cent.

Sudeten larch from Silesia. Supplied by J. Rafn & Son. Location not recorded. 1932 crop. Identity No. 33/46. Germination 34·8 + 2·4 per cent.

Darnaway Estate, Moray. Presented by the Earl of Moray. Lat. 57° 35′ N. Long. 3° 40′ W. Provenance of parent trees not recorded. 1932 crop. Identity No. 33/513. Germination 59·6 + 0·8 per cent.

Addendum 2

Experimental Site Data

Block and Forest:	Tirinie, Drummond Hill forest, Perthshire	Auchindinnie, Clashindarroch forest, Aberdeenshire
Compartment ..	99A.	58.
Latitude and longitude	56° 37′ N. 3° 57′ W.	57° 23′ N. 2° 54′ W.
Elevation, ft. ..	420–480 ft.	1,000–1,050 ft.
Relative elevation ..	On the edge of the flattish Tay valley. Steep hill immediately to north rises to 1,557 ft.	Upper slopes of valley of Lag burn, 150 ft. below. Hill rises gently to north to nearly 1,150 ft.
Exposure ..	Moderate.	Moderate.
Aspect	South.	South.
Slope	Moderate 12°.	Moderate 15°.
Topography	A fairly even slope.	An even slope.
Geology ..	Highland mica schists of the Dalriadan succession.	Highland schists. Boyndie Bay group of andalusite schists. Knotted laminated phyllite with bands of pebbly grit and quartzose slates.
Soil	0–2 in. Raw and partly decomposed litter. 2–9 in. Grey-brown fine sandy loam, crumb structure. Numerous fine mica crystals. 9–18 in. Fine sandy loam, light brown, merging downwards to yellow brown mica schist and stones. 18–27 in. Yellow brown sandy loam. Freely drained and free rooting.	0–3 in. Litter and mor humus. 3–6 in. Dark brown clay loam, crumb structure. 6–12 in. Light brown clay loam. 12–20 in. Light brown loam, full of stones. Freely drained. 20 in. +. Very compact and stony layer. Brown earth—creep soil (Muir and Fraser, 1940). Foundland Association, Series 2, Intermediate depth. (Glentworth, 1954).
Rainfall per annum ..	39 in.	38 in.
Vegetation before planting.	*Pteridium aquilinum*, over grass/herb association, following *Pinus sylvestris* felled about 1905–6.	*Calluna vulgaris* dominant and luxuriant, *Erica cinerea* abundant. *Empetrum nigrum*, occasional herbs and mosses. Used for grazing sheep until 1933.
Expt. No.	7, P. 35.	18 p. 35.

APPENDIX I

List of Main Experimental Projects and the Localities where Work is Concentrated

While most of the investigations and experiments of the Research Branch are scattered throughout forests all over the country, there are certain areas where work on some projects is more or less concentrated. These are briefly given below:

NURSERY EXPERIMENTS

Benmore Forest Nursery, near Dunoon (Argyll)
Bramshill Nursery (Hampshire)
Bush Nursery, near Edinburgh.
Fleet Forest Nursery, Gatehouse of Fleet (Kirkcudbrightshire)
Inchnacardoch Forest Nursery, near Fort Augustus (Inverness-shire)
Kennington Nursery, near Oxford.
Newton Nursery, near Elgin (Morayshire)
Sugar Hill Nursery, Wareham Forest (Dorset)
Tulliallan Nursery (Fife) near Alloa

AFFORESTATION EXPERIMENTS ON PEAT

Achnashellach Forest (Ross-shire)
Beddgelert Forest (Caernarvonshire)
Clocaenog Forest (Denbighshire)
Inchnacardoch Forest (Inverness-shire)
Kielder Forest (Northumberland)
Strathy Forest (Sutherland)
Wauchope Forest (Roxburghshire)

AFFORESTATION EXPERIMENTS ON HEATHLAND

Croft Pascoe Forest (Cornwall)
Harwood Dale in Langdale Forest (Yorkshire)
Teindland Forest (Morayshire)
Wareham Forest (Dorset)
Wykeham and Broxa in Allerston and Langdale Forests (Yorkshire)

NUTRITION OF ESTABLISHED CROPS

Bramshill Forest (Hampshire)
Haldon Forest (Devon)
Tarenig Forest (Cardiganshire)
Wareham Forest (Dorset)
Wilsey Down Forest (Cornwall)

CONVERSION OF COPPICE

Alice Holt Forest (Marelands), (Hampshire)
Forest of Dean (Penyard) (Hereford)
Gardiner Forest (Wilts)

PROVENANCE EXPERIMENTS

Scots pine:	Findon Forest (Easter Ross) Thetford Chase (Norfolk)
Lodgepole pine:	Achnashellach Forest (Wester Ross) Clocaenog Forest (Denbigh) Millbuie Forest (Easter Ross) Wykeham in Allerston Forest (Yorkshire)
European larch:	Coed y Brenin (Merioneth) Savernake (Wilts) Mortimer (Hereford)
European and Japanese larches:	Clashindarroch Forest (Aberdeenshire) Drummond Hill Forest (Perthshire) Lael Forest (Wester Ross)
Douglas fir:	Glentress Forest (Peebles-shire) Laiken Forest (Nairnshire) St. Clements (Cornwall) Mortimer (Salop)
Norway and Sitka spruces:	Newcastleton Forest (Roxburghshire) The Bin Forest (Aberdeenshire)
Sitka spruce:	Radnor Forest (Radnor)
Beech:	Queen Elizabeth Forest (Hampshire) Savernake (Wilts)

PRUNING EXPERIMENTS

Drummond Hill Forest (Perthshire)
Monaughty Forest (Moray)

PLANTING EXPERIMENTS ON SAND DUNES

Newborough Forest (Anglesey)

PLANTING EXPERIMENTS ON CHALK DOWNLANDS

Friston Forest (Sussex)
Queen Elizabeth Forest (Buriton, Hants and Sussex)

ESTABLISHMENT OF OAK

Forest of Dean (Gloucester, Hereford and Monmouth)
Dymock (Gloucester and Hereford)

POPLAR TRIALS AND SILVICULTURAL EXPERIMENTS

Blandford (Dorset)
Cannock (Stafford)
Doncaster (Yorkshire)
Dyfnant (Montgomeryshire)
Forest of Dean (Gloucester)
Harling, Thetford Chase (Norfolk)
Hookham, Thetford Chase (Norfolk)
Quantock Forest (Somerset)
Stenton (East Lothian)
Wynyard (Durham)
Yardley Chase (Beds and Northants)

SPECIES PLOTS

Beddgelert Forest (Caernarvonshire)
Bedgebury Forest (Kent)
Crarae, near Minard Forest (Argyll)
Benmore Forest (Argyll)
Thetford Chase (Norfolk)
Wareham Forest (Dorset)

GENETICS

Propagation Centres
Alice Holt (Hampshire)
Grizedale (Lancashire)
Westonbirt (Gloucestershire)
Bush (Midlothian)

Tree Banks
Newton (Morayshire)
Alice Holt (Hampshire)
Rendlesham (Suffolk)
Bush (Midlothian)
Bradon (Wiltshire)

Seed Orchards
Newton (Morayshire).
Ledmore (Perthshire)
Drumtochty (Kincardineshire)
Archerfield and Whittingehame (East Lothian)
Alice Holt (Hampshire)
Bradon (Wiltshire)
Forest of Dean (Gloucestershire)
Rendlesham (Suffolk)

PATHOLOGICAL RESEARCH AREAS

Moorburnhead (Dumfries-shire):	Group dying of Conifers
Glenfinart (Argyll):	Group dying of Conifers
Haldon (Devon):	Resin bleeding of Douglas fir
Harling, Thetford (Norfolk):	Fomes annosus
Mundford, Thetford (Norfolk):	Bacterial canker of poplar
Queen Elizabeth Forest (Hampshire)	Wound Protectants

ARBORETA

Bedgebury Pinetum (Kent)
Westonbirt Arboretum (Gloucestershire)

APPENDIX II

Staff of Research Branch as at 31st March, 1958

DIRECTORATE OF RESEARCH AND EDUCATION. 25, Savile Row, London, W.1. Tel.: Regent 0221.

J. Macdonald, C.B.E., F.R.S.E. ..	Director
Miss A. Brooks, M.B.E.	Senior Executive Officer

FOREST RESEARCH STATION. Alice Holt Lodge, Wrecclesham, Farnham, Surrey. Tel.: Bentley 2255.

M. V. Laurie, O.B.E., M.A., Dip. For. ..	Conservator, Chief Research Officer.
R. Rendle ..	Higher Executive Officer

MACHINERY

R. G. Shaw, B.A., A.M.I.Mech.E. ..	Machinery Research Officer

UTILISATION DEVELOPMENT

E. G. Richards, M.C., B.Sc.	Divisional Officer.
C. D. Begley, B.Sc.	District Officer
J. R. Aaron, M.A.	,, ,,

SILVICULTURIST (SOUTH) (Alice Holt)

R. F. Wood, B.A., B.Sc.	Divisional Officer
M. Nimmo	District Officer
G. D. Holmes, B.Sc.	,, ,,
J. R. Aldhous, B.A.	,, ,,
A. D. S. Miller, B.Sc.	,, ,,
J. Jobling, B.Sc.	,, ,,
J. M. B. Brown, B.Sc., Dip. For. ..	,, ,,
W. H. Hinson, B.Sc., Ph.D.	Scientific Officer
G. Buszewicz, Mgr. Ing.	Experimental Officer.

SILVICULTURIST (NORTH). Government Building, Bankhead Avenue, Sighthill, Edinburgh, 11. Tel.: Craiglockhart 4010.

M. V. Edwards, M.A.	Divisional Officer
G. G. Stewart, M.C., T.D., B.Sc.	District Officer
R. Faulkner, B.Sc.	,, ,,
R. Lines, B.Sc.	,, ,,
D. W. Henman, B.Sc.	,, ,,

MANAGEMENT (Alice Holt)

F. C. Hummel, M.A., D.Phil.	Divisional Officer
A. M. Mackenzie (Edinburgh)	District Officer
G. M. L. Locke, B.Sc.	,, ,,
A. J. Grayson, M.A.	,, ,,
D. Johnston, B.A.	,, ,,

STATISTICS

J. N. R. Jeffers, A.I.S.	Senior Scientific Officer

FOREST PATHOLOGY

T. R. Peace, M.A.	Divisional Officer
J. S. Murray, B.Sc.	District Officer
S. Batko, D. Ing.	

FOREST ENTOMOLOGY

M. Crooke, B.Sc., Ph.D.	District Officer
D. Bevan, B.Sc.	,, ,,
Miss J. Davies, B.Sc.	Experimental Officer

FOREST GENETICS

J. D. Matthews, B.Sc.	District Officer
A. F. Mitchell, B.A., B.Ag.	,, ,,

DOCUMENTATION AND PHOTOGRAPHY

G. D. Kitchingman, M.A., Dip. For.	District Officer
H. Cruickshank, M.A., B.Sc.	,, ,,
I. A. Anderson	Principal Photographer
Miss T. K. Wood	Photographer

APPENDIX III

List of Publications

The following papers by members of the Research Branch staff were published during the year ended 31st March, 1958.

Aaron, J. R.	Conifer Barks as a Source of Tannin. *Scot. For.* 11, 1957. (72–76).
Buszewicz, G., and Holmes, G. D.	Seven Years Seed Testing Experience with the Tetrazolium Viability Test for Conifer Species. *Rep. For. Res. For. Comm., Lond.* 1957. (142–51).
Crooke, M.	Host of the Overwintering Generation of *Trichogramma evanescens.* Westw. *Ent. Mon. Mag.* 92, 1956. (368).
Crooke, M.	A brief review of the British conifer feeding sawflies. *Z. angew. Ent.* 41, 1957 (179–83).
Crooke, M.	*Experiments on the Control of the Pine Weevil, Hylobius abietis,* L. Seventh Brit. Comm. For. Conf. Papers, 1957.
Crooke, M., and Bevan, D.	Notes on the First British Occurrence of *Ips cembrae,* Heer (Col. *Scolytidae*). *Forestry* 30, 1957 (21–28).
Evans, W. R., and Christie, J. M.	*Provisional Yield Table for Western Hemlock in Great Britain.* For. Rec. For. Comm., Lond. No. 33, 1957. (H.M.S.O. 1*s.* 9*d.*).
Faulkner, R.	Investigation into Intensive Methods of Raising Conifer Seedlings. *Emp. For. Rev.* 37, 1958 (85–95).
Faulkner, R.	Scottish Experiments comparing Chloropicrin with Formalin as a Partial Soil Sterilizer for Conifer beds. *Rep. For. Res. For. Comm. Lond.* 1957 (159–170).
Finch, H. D. S.	Plotless Enumeration with Angle Gauges. *Forestry,* 30, 1957 (173–192).
Finch, H. D. S.	*New Ways of Using the General Tariff Tables for Conifers.* For. Rec. For. Comm., Lond. No. 32, 1957. (H.M.S.O. 1*s.* 3*d.*).
Grayson, A. J.	How should we grow Conifers? Report of Forestry Conference at Dartington Hall. *Quart. J. For.* 51, 1957 (322–331).
Hinson, W. H., and Reynolds, E. R. C.	Cation Adsorption and Forest Fertilisation. *Chem and Ind.* 1958 (7), (194–6).
Hummel, F. C.	Report on Visit to Soviet Union, Part I. *Emp. For. Rev.* 36, 1957 (251–65), and Part II *ibid.* 37, 1958 (49–65).
Hummel, F. C.	Yield Regulation and Forecasts of Production. *Irish For.* 14, 1957 (100–107).
Hummel, F. C.	Methods of Forecasting Production from Thinnings in Great Britain. *Unasylva,* 12, 1958 (67–71).

Hummel, F. C., and Christie, J. M.	Methods Used to Construct the Revised Yield Tables for Conifers in Great Britain. *Rep. For. Res. For. Comm., Lond.* 1957 (137–41).
Hummel, F. C., and Grayson, A. J.	The Achievement of Sustained Yield by Varying Thinning Treatment and Rotation. *Forestry* 30, 1957 (105–121).
Jeffers, J. N. R.	Volumes of Timber Used in Fencing. *Quart. J. For.* 52, 1958 (58–60).
Jeffers, J. N. R., and Howell, R. S.	Use of a Fractionally-Replicated Design in a Pilot Survey of Moisture Content and Specific Gravity of Spruce and Pine Bark. *Rep. For. Res. For. Comm., Lond.* 1957 (151–9).
Laurie, M. V.	*Planning a Forestry Research Programme.* Seventh *Brit. Comm. For. Conf.* Papers 1957.
Lines, R.	*Pinus contorta* in Ireland, 1955. *Forestry* 30, 1957 (139–150).
Macdonald, J.	Forest Research in England and Wales. *Quart. J. For.* 50, 1956 (267–277).
Macdonald, J.	The International Union of Forest Research Organisations Congress in Oxford. *Nature* 178 (6th Oct. 1956) (730–732).
Macdonald, J.	A visit to the Caucasus. *J. Oxford. Univ. For. Soc.* 1957.
Macdonald, J., Wood, R. F., Edwards, M. V., and Aldhous, J. R.	*Exotic Forest Trees in Great Britain.* Bull. For. Comm., Lond. No. 30, 1957. (H.M.S.O. 17*s.* 6*d.*).
Matthews, J. D., and McLean, C.	*Improvement of Scots pine in Britain by Selection and Breeding.* Seventh Brit. Comm. For. Conf. Papers 1957.
Mitchell, A. F.	List of Tallest and Largest Commoner Trees Recorded since 1947. *Quart. J. For.* 51, 1957 (333–336). Revised and Reprinted in J.R. *Hort. Soc.* 83, 1958 (111–5).
Murray, J. S.	*Top Dying of Norway Spruce.* Seventh Brit. Comm. For. Conf. Papers. 1957.
Peace, T. R.	Approach and Perspective in Forest Pathology. *Forestry* 30, 1957 (47–56).
Peace, T. R.	Raising of *Thuja* in Isolated Nurseries to Avoid Infection by *Keithia thujina. Scot. For.* 12, 1958 (7–10).
Peace, T. R.	*Recent Observations on the Rusts of Pine in Britain.* Seventh Brit. Comm. For. Conf. Papers. 1957.
Peace, T. R.	A Single Case of Fume Damage. *Quart. J. For.* 52, 1958 (41–45).
Peace, T. R., Murray, J. S., and Batko, S.	*Sclerophoma pithyophila* associated with Needle-cast of Pines and its Connection with *Pullularia pullulans. Trans. Brit. mycol. Soc.* 41, 1958 (126–8).
Shaw, R. G.	British Machinery in the Forest. *Farm Mechanisation,* March 1958.

Shaw, R. G., Holmes, G. D., and Miller, A. D. — Problems of Land Reclamation: 6. Clearing Scrub Vegetation. *Agric. Rev.* July, 1957 (31–36).

Waters, W. T., and Christie, J. M. — *Provisional Yield Tables for Oak and Beech in Great Britain.* For. Rec. For. Comm., Lond. No. 36. 1958. (H.M.S.O. 2*s.* 6*d.*).

Wood, R. F. — The British Association Meeting, Dublin, Sept. 4–11, 1957. (Section K^{x} Forestry) *Emp. For. Rev.* 37, 1958 (14–18).

Wood, R. F., and Matthews, J. D. — *The Performance of Eastern North American Trees in Great Britain.* Contribution to Colloque International à la Memoire de François—André Michaux, Centre National de la Recherche Scientifique, Paris. 1957.

In addition, Mr. J. S. Murray of the Research Branch staff assisted in the compilation of the Forestry Commission Leaflet No. 43, *Keithia Disease of Thuja plicata.*

(75219) Wt. 3572/2552 K.23 5/59 Hw.