FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1951

LONDON: HER MAJESTY'S STATIONERY OFFICE
1952
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INTRODUCTION

By JAMES MACDONALD
Director of Research and Education

This report, which covers the work of the year that ended on 31st March, 1951, follows the same lines as its predecessors. That is to say, it is in two sections. In the first section, the work carried out by the staff of the Forestry Commission's Research Branch is reviewed at some length in the course of a number of chapters, each on a different subject, and written by the officer or officers who have been most directly concerned. The second section covers the work which has been conducted for the Commissioners by Universities and other Institutions on problems mainly of a more fundamental character. The various chapters have been summarized by the Chief Research Officer, Mr. M. V. Laurie, in a preliminary note.

Last year, reference was made to the expansion of the Forestry Commission's own work, resulting from the formation of a section dealing with the mechanisation of forestry operations. On this occasion, another increase in activity falls to be recorded. During the year, the Forestry Commissioners, having set up an Advisory Committee on the Utilisation of Home-grown Timber, established a section under the Director of Research, to carry out investigations into the marketing and utilisation of produce from woodlands and forests in Great Britain. The work of this new section, which is likely to become of considerable importance, had not progressed sufficiently far by the end of the year under review to justify any statement in the body of this Report, but its work will be recorded annually in the future. The Director of the Forest Products Research Laboratory, who is a member of the Advisory Committee on Forest Research, is also represented on the new Utilisation Committee, and the officer in charge of the newly-formed section will keep in close touch with Princes Risborough.

There have been no developments of a major character on the silvicultural side, but this *Report* gives summaries of work which has been under way for some time on the natural regeneration of the old Scots pine woods in the Highlands, and on the use of a larch mixture in the formation of oak plantations, a subject which has been under observation for a number of years in the southern part of the country.

Another section summarises the results of a survey of plantations which had been formed on old ironstone workings on several estates in the Midlands; it is intended to publish a fuller account of this work in another form.

The Research Station at Alice Holt has now been equipped for seed-testing, and in the future the Commission's stocks of seed will be tested in the laboratory there. This work fits in well with the other investigations on seed which have been going on for some time.

During the year, the Advisory Committee on Forest Research held two meetings at which the programme of research was reviewed. The first of these meetings was held at Northerwood House, in the New Forest, from 29th September to 1st October, 1950, and the second in London on the

15th March, 1951. While they were at Northerwood, the Committee were able to visit nursery experiments at Ringwood and Wareham, and experiments in cut-over woodlands at Gardiner Forest, Wiltshire.

The Sub-Committee on Nutrition in Forest Nurseries, which has continued its important work, met at Oxford from the 2nd to the 4th of October, 1950. The work of this Sub-Committee has thrown much light on the complex problems with which it is faced, and thanks are due particularly to Dr. E. M. Crowther of Rothamsted and Dr. A. B. Stewart of the Macaulay Institute for Soil Research and their staffs for all the work they have done. Thanks are also due to the Directors of these Institutions for the facilities which they have made available to the Sub-Committee.

There has been a marked increase in the number of visitors to Alice Holt, and to the various experimental areas in different parts of the country. At the same time contacts have been maintained with the Universities and other scientific Institutions, many of which have given valuable assistance which is gratefully acknowledged here.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE
Chief Research Officer

Staff

The Chief Research Officer's headquarters were transferred from the Forestry Commission Research Station at Alice Holt Lodge to the Forestry Commission headquarters at 25 Savile Row, London, W.1. He continued at the same time to supervise the work of the Research Station. Mr. J. S. R. Chard, who completed his work as Chief Census Officer, was transferred in June to the staff of Director, England. Mr. E. G. Richards joined the headquarters staff as Utilisation Development Officer. Mr. R. Faulkner took up duty in Edinburgh as Assistant Silviculturist, in charge of the nursery experiments in the North. Mr. R. C. Stern began duty at Alice Holt, but within two weeks had to report for National Service. Mr. J. Jobling was appointed Assistant Silviculturist to work on poplars, Miss T. K. Wood was appointed Photographer, to assist the Senior Photographer, Mr. W. O. Wittering was appointed Executive Officer, *vice* Miss J. M. A. Sharpe who was transferred to the staff of Director, England.

Forest Research Station, Alice Holt

The lack of accommodation continues to be a problem. Three more huts have been obtained to provide additional office and storage space. Work on a Nissen hut to serve as the canteen is almost complete, and will free space for laboratory accommodation to cope with the increase of work which will follow the decision to make Alice Holt Lodge the Department's seed-testing station.

During the year, official visitors to the station totalled 136, and included people from Australia, British Guiana, Canada, China, Denmark, Sweden, Tanganyika, Trinidad, Turkey, Uganda and the United States of America.

The Year's Work

This report is, as usual, in two parts, namely:—

Part I —Work carried out by staff of the Forestry Commission Research Branch.

Part II—Work on special problems—often of a more fundamental nature—carried out by Universities and other Institutions with the help of grants from the Forestry Fund.

The following is a brief summary of the main items of interest in the reports which follow:

1. Forest Tree Seed Investigations

A large number of cone samples taken prior to bulk collection were examined, and the viability of the immature seeds tested by the "tetrazolium" method. Recommendations were made on the suitability or otherwise of each stand for bulk collection. Systematic work on the seed storage of beech and oak has commenced, using, among other treatments, controlled low temperature storage. Four years work on seed pretreatment by soaking was concluded, and indicated that for the species tested, namely Sitka and Norway spruces, Japanese larch and Scots pine, soaking is not worth while. (See page 13.)

2. Nursery Experiments

In England most of the experimental work in nurseries was done in connection with the programme of the Sub-Committee on the Nutrition Problems in Forest Nurseries, and is reported on by Dr. Crowther in Part II of this *Report*. (See page 113.) Other work done by the Forestry Commission Research Branch (see pages 15 to 26) included further studies of partial sterilisation of soils in old-established nurseries, in which it was found that residual effects after two years on height growth of seedlings were still appreciable both for steam and formalin treatments, and that steam had the greatest residual effect on weed control. Various methods of sealing beds after application of formalin, to try and retain the vapour and make the sterilisation more effective did not, in fact, give any improvement. Trials with "D-D" soil fumigant showed it to be much less effective than formalin. Acidification treatments, using both sulphur and ammonium sulphate, done in 1948 at Newton Nursery, Morayshire, still showed significant residual effects on Sitka spruce seedlings. Acidification in certain other nurseries in 1950 gave no beneficial results, indicating that some other factor was limiting seedling growth.

In nursery manuring, drilling of fertilisers beneath the seed rows again gave some increase in growth, but the results are not yet sufficiently good to warrant the adoption of drilling of fertilisers as a nursery practice. In testing various forms of nitrogen, "flash" (i.e. formaldehyde plastic waste) and formalised casein produced the largest and greatest outturn of usable seedlings in most nurseries. Vegetable meal and fish guano both tended to depress growth and adversely affect germination.

In an experiment to see whether hopwaste manuring on a new heathland nursery site could be replaced by growing a green crop and digging it in, some curious interactions between additional fertilisers and the green crop and hopwaste compost respectively, were observed. On the previously green-cropped land the fertilisers (potash and phosphate) gave greatly increased growth, while with the compost they reduced it. Further experiments will have to be done to verify these results.

COVERING MEDIA ON SEEDBEDS

Some interesting results with different seed covering media in common use in various conservancies were obtained. Most of the types of grit and sand used were satisfactory, exceptions being the whinstone chips used at Wauchope, Roxburghshire, and Loch Lochy grit used in Inchnacardoch heathland nursery Inverness-shire. Carlops No. 4 sand gave uniformly good results in the five nurseries where it was tried—the only material that was better being Doncaster quartzite grit used at Wauchope nursery. These results will require confirmation.

SEEDBED WATERING AND IRRIGATION

In the wet season of 1950 at Kennington nursery (8.6 inches from June to September) overhead irrigation had negligible effect on the growth of all species tried except Sitka spruce, where greatly increased production of seedlings and increase of height growth was obtained. The necessity for liberal application of fertilisers to counteract losses through leaching was demonstrated.

COMPOSTING AND TRIALS OF COMPOST

On heathland soils, composts made from sawdust or heather as base materials did not improve the growth of Sitka spruce seedlings, but all straw composts considerably increased growth and yield. Slaughterhouse blood applied to beds the previous autumn, at 4,500 gallons per acre, increased the growth of Sitka spruce seedlings the following season to an extent approximately equal to that resulting from an application of twenty tons of bracken/blood or bracken/hops compost per acre. In composting straw, the addition of fifteen per cent. by volume of succulent material, such as grass mowings, along with the nitrogenous activator, greatly improved breakdown. Satisfactory straw composts can be prepared using ammonium sulphate or nitrochalk, providing a moisture retainer is added and acid conditions prevented.

GRASS LEYS AND GREENCROPPING

Two years of greencropping or of grass leys at Kennington Nursery near Oxford, produced no improvement in the growth and yield of Sitka spruce seedlings as compared with beds continuously cropped with Sitka spruce.

CHEMICAL CONTROL OF WEEDS IN NURSERY BEDS

Pre-emergent sprays of various vaporising oils and white spirits applied four to five days before the crop germinates give 90 to 100 per cent. kill of weeds without appreciable damage to the tree crop. Many oils and compounds were tested as post-emergent sprays. It was found that certain white spirits and vaporising oils were highly selective, giving good kills of heavy weed populations with less damage to seedlings than is caused by hand weeding. The pines were found to possess the highest degree of resistance to oils. Spruces are more susceptible, but if white spirits are used the number of seedlings killed is far outweighed by the saving in hand weeding. Douglas fir and Japanese larch appear to be too susceptible to permit post-emergence spraying to be used.

3. Forest Investigations

Mr. J. A. B. Macdonald contributes a note on natural regeneration of native Scots pine, summarising the results of a number of investigations, and attempting to analyse the factors which have prevented natural regeneration from appearing in most of the areas studied. Recommendations are given for securing regeneration. Contrary to many natural regeneration problems, the general prescription of patience does not seem to apply, as conditions for securing regeneration become rapidly more unfavourable each year after a seeding felling has been made. The recommendations in brief are, to thin fairly heavily so as to get good crowns on the trees some years before it is intended to regenerate the area, wait for a good seed year before making the felling, and when this is made, burn the heather if possible and stir up the ground with disc or tine harrows. If seeding is successful, apply phosphate and possibly nitrogenous fertilisers to selected seedlings. If seeding is unsuccessful by the end of the second year, spend no more money on trying to get natural regeneration, and plant up the unstocked areas. (Page 26.)

In planting on ploughed heathland, the position of planting is of importance. Experiments have shown repeatedly that planting on top of the ridge of soil turned out by the plough, a common practice, is one of the worst positions as regards survival and subsequent growth. The bottom of the furrow is a good position, but planting in the side of the furrow is the best. This does not apply to planting on ploughed deep wet peat where the furrows serve to drain the soil. (Page 33.)

PROVENANCE STUDIES

For European larch, some new provenance trials have been laid down in areas where a previous crop of that species was practically wiped out by "die-back" disease. Polish, Japanese and hybrid larches are included in the trials, which should give interesting and useful results. Assessments of rate of growth, the number and diameter of branches, and amount of canker on some earlier experiments (planted 1936-1938) have shown that, in Perthshire, the Silesian origins are the most vigorous, the finest branched and the least susceptible to canker, while the Swiss and French alpine provenance from high elevations are the worst in this respect. Scottish provenances, which are of unknown ultimate origin, are intermediate.

Similar studies of hybrid larch indicate that it is a relatively finely branched tree. Nursery studies of free-pollinated seed from the "Avenue" Japanese larch trees at Dunkeld, Perthshire, indicate higher average vigour for the hybrids than for the plants with Japanese characteristics, or with intermediate characteristics. (Page 38.)

OAK AND LARCH MIXTURES

A summary of experience with oak-larch mixtures raised experimentally in five different forests which have reached the pole stage, is given. On the whole, for ease in management, strip mixtures appear to be preferable to group mixtures, though each has its points. It is evident that wider spacings in the oak (up to 4 ft. x 4 ft.) could be utilised and it seems probable that the numbers of plants in groups could be reduced to about twelve. Relative rates of growth of oak ano larch vary on different sites, but larch is so much faster that it is clear that the space between it and the nearest oak should not be less than five feet. There is an indication of a slight nursing effect by larch on the oak. (Page 46).

PLANTATIONS ON OPENCAST IRONSTONE AREAS

A detailed survey and assessment of plantations on old opencast mining areas in the Midlands has been made. In general larch, particularly hybrid larch, and sycamore, have been the most successful species on the majority of soils. Spruces and Douglas fir were unsuccessful, as also were ash, oak and elm. Scots pine and Corsican pine have done fairly well, the latter giving higher production in older plantations. (Page 51.)

DERELICT WOODLAND INVESTIGATIONS

A reclassification of the derelict woodland areas given in the Census of Woodlands for the South East and South West Conservancies of England according to underlying geology, soil and forest type, has indicated where the bulk of the problem lies. Nearly half the area lies on the fertile and moderately fertile loam soils (about 117,000 acres out of 243,000 acres) indicating the desirability of concentrating on these soils. Less than one sixth (40,000 acres) lies on the chalk and oolite types. "Scrub" was the predominant forest type, constituting nearly one third of the area (76,000 acres) while one sixth (38,500 acres) was classed as "Devastated". Coppice and Coppice-with-Standards of uneconomic types together made up about a quarter (66,000 acres), the balance being felled areas and derelict broadleaved high forest. (Page 54.)

Work has progressed in the Weston Common demonstration area at Alton Forest, Hants., according to plan. So far the income from the sales of produce has exceeded the cost of clearing or treating the existing crop. In one area of 10.7 acres where stocking of valuable species was irregular, eighty large beech plants, eight to ten feet high, were planted to enrich the stock. Although rather expensive, these plants have almost all taken and, in spite of a sea of bracken six and a half feet high, will require very little tending.

A carefully costed experiment was done, comparing five different methods of treating hazel coppice with a view to converting it to beech high forest. The initial clearing and planting, including cost of plants, worked out as follows:

	Initial cost per acre		
Small groups 12 feet square at 21 foot centres, 5 beech plants per group = 490 plants per acre	£12	16	6
Large irregular groups roughly 30 feet square, 25 beech plants per group = 625 plants per acre	£17	14	6
Cleared strips 12 feet wide leaving 10 feet of uncleared coppice —beech plants at 4 ft. x 3 ft. = 987 plants per acre	£23	4	6
Thinning the hazel to leave light uniform canopy and underplanting with beech at 4 ft. x 4 ft. = 2,540 plants per acre	£40	9	0
Complete clearance of coppice and planting throughout with beech at 4 ft. x 4 ft. = 2,532 plants per acre	£47	13	0

This apparently unattractive old coppice was, however, saleable, and if the sale value is considered, the approximate net costs work out at:

	Net cost per acre		
Small groups	£4	14	6
Large groups	£9	5	6
Strips	£10	10	0
Thinning and underplanting	£33	7	0
Clear cutting	£25	2	0

Subsequent tending costs, which will undoubtedly be highest in the small groups, may ultimately alter the order of final costs of the different methods of establishing the beech crop.

INFLUENCE OF SHADE ON GROWTH OF BEECH

Studies of the factors affecting the early growth and form of beech, by Mr. A. D. Miller and Mr. J. M. B. Brown, have indicated that light intensities down to about twenty per cent. of full overhead light have scarcely any appreciable effect on the rate of height growth of young beech, but below twenty per cent. serious retardation may be caused. The incidence of forks appears to be mainly connected with actual damage to the leading shoot, particularly lammas shoots, and is not noticeably affected by different degrees of shade. The persistence of forks, however, is less if the plant is in a shaded position. Other effects of shade on form are also described in Mr. Brown's report. (Pages 61 and 62.)

EFFECT OF HIGH PRUNING ON THE SUBSEQUENT COST OF BARK-PEELING

An investigation in Douglas fir showed that high pruning does not reduce the subsequent cost of peeling bark from Douglas fir poles, and underlined the point already appreciated that pruning is only worth while if the pruned stems ultimately reach timber size.

4. Forest Genetics

Progress in the improvement of the inherent quality of our more important species is described. (Page 74.)

CORSICAN PINE. Over 600 acres of plantations have been selected as "Plus" stands for seed collection after a survey of plantations. Seed production in twenty-year-old stands can be materially increased by strangulation or girdling, but crown size is the most important factor in cone production. Thirty individual "plus" trees have been selected with a view to progeny trials. Vegetative propagation of this and other pines has been found to be difficult, and intensive experimentation has been going on to find the best method.

BEECH. Few "plus" stands were found, the total area selected being less than 400 acres. Progeny trials of grafts from selected trees and of seed from various provenances in the country have continued, and initial differences seen in the nursery last year have been maintained. In new progeny trials, seed from 40 "plus" trees in Britain (free-pollinated) is being compared with seed from nineteen foreign origins (France, Belgium, Germany, Holland, Denmark, Czechoslovakia and Austria), and nine other home origins varying from "plus" through "normal" to "minus". Beech is notoriously difficult to graft, and intensive experimentation in the best methods of propagating it vegetatively is in progress.

LARCH. "Plus" trees of European and Japanese larch have been selected in North-East Scotland and the Lake District, and the first "seed orchard" from propagated material has been laid down at Newton, near Elgin, Morayshire. Larch is found to be easy to graft, but not so easy to raise from cuttings. Intensive work is going on to find the best conditions for the latter, which, if successful, might lead to the production of hybrid larch from individuals of known excellence, in sufficient quantities for regular forest planting.

SCOTS PINE. Parent trees for use in a future seed orchard have been selected, and grafts made. *Pinus mugo* has been successfully used as a rootstock for Scots pine grafts.

SITKA SPRUCE. A survey was made in the summer of 1950 of the different morphological types of Sitka spruce, with a view to selecting "Plus" trees possessing superior vigour and growth form, hardiness to late frosts and resistance to *Neomyzaphis* attack. 40 trees have been selected and propagated, and testing of their genotypic characters is commencing. Sitka spruce flowers readily at a young age, and seed from a number of these trees (from free-pollination) is being raised in the nursery. The propagation of Sitka spruce from root cuttings seems also to be an easy and convenient method of raising it.

DOUGLAS FIR. The variation in type of this species in Britain is very wide. In the course of a survey some "plus" trees have been selected. It appears that the strain of Douglas fir grown at Scone Estate (Perth) is particularly good and worthy of further cultivation.

X CUPRESSO CYPARIS LEYLANDII. This hardy and fast-growing hybrid cypress is a first generation cross between *Cupressus macrocarpa* and *Chamaecyparis lawsoniana*, and, like hybrid larch, to get the best results, first generation plants should be used. Work has concentrated therefore on methods of vegetative propagation of this hybrid suitable for large scale production, and a good deal has been discovered about the best type of cutting, the best propagating conditions, the best media to use and the effect of growth promoting substances. More work is necessary before we can recommend the best practice.

NORWAY AND SITKA SPRUCES. Late- and early-flushing plants (as observed in the nursery in 1948) have been planted out in a frosty locality in Newcastleton (Roxburghshire). Their relative differences in dates of flushing persist in the forest, and it will be interesting to see to what extent this is correlated with frost damage.

5. Poplars

The clone collections numbered 224 different clones at the end of the year under review. Varietal trials of promising clones have now been established at seventeen different localities. Experiments are in progress on the technique of raising poplar plantations, including such points as age and type of plant or cutting to use, methods of planting, mulching, manuring, etc., on various different site types. Certified cuttings of four varieties, *P. serotina*, *P. serotina* (narrow crowned variety), *P. gelrica* and *P. robusta* were supplied to nurserymen and to Forestry Commission nurseries for the third consecutive year, in increased quantity. (Page 83.) In October, 1949, poplars were brought within the *Importation of Forest Trees Order*; import licences are now normally limited to properly certified varieties known to be resistant to disease. Studies on disease resistance, in particular to bacterial canker and *Melampsora* rust, were continued. The leaflet on poplars was revised and re-issued.

6. Studies of Growth and Yield

Thirty-four new permanent sample plots for yield table purposes were established, bringing the total up to 458 (three old plots having been written off). Some of the new plots were laid down in larch provenance experiments to give comparative crop production data for larch of different seed origins. In the comparative thinning plots in Bowmont Forest (on the Duke of Roxburghe's estate, Roxburghshire) the D-grade and light-crown thinning grades have produced a higher total increment than the lighter B and C thinning grades. This is an exception to the almost universal experience that total increment is not appreciably affected by variation in thinning grade.

334 temporary hardwood sample plots were measured, 144 of oak, 100 of beech, 35 of ash and 55 of other hardwoods. Considerable time was spent on preparing estimates indicating, on a national scale, the probable short-term and long-term effects of various felling regimes on the growing stock and increment of the forests in Great Britain.

An increasing volume of work on the statistical analysis of experiments was dealt with, and a nucleus of a statistical section for doing such work has been formed. A number of new methods of analysis were introduced for special types of experiments, and advice given on sampling techniques for various purposes. A start has been made on preparing a comprehensive account of the various statistical procedures used by the Research Branch of the Forestry Commission.

General volume tables for Scots pine, European larch, Norway and Sitka spruces, and Corsican pine were completed. The revision of the yield tables for conifers has been continued. Revised thinning schedules were prepared for the (1951) new edition of Forestry Commission Bulletin 14, *Forestry Practice**. In general, the new thinning schedules start earlier and are heavier than the old ones.

An investigation into methods of sampling for forest enumerations, indicated that satisfactory estimates of volume and increment of a 500-acre forest could be obtained under proper sampling methods with a sampling fraction of only one per cent. Two men can cover approximately 1,000 acres in a fortnight in this type of survey. Further work on this subject is in progress.

7. Census of Woodlands

The census of timber in hedgerows, small woods under five acres, and all unproductive woods, was completed and the results computed. A complete picture is now available of the timber resources of the country.

It is interesting to note that no less than twenty-one per cent. of the standing timber volume of Great Britain is in hedgerows.

CENSUS MAINTENANCE. Methods for keeping the census figures up-to-date are still under trial. That now proposed is to correct the figures for each county annually, from a record of the fellings and plantings by counties, and this method is being tested for one Conservancy. Periodical field checks will be necessary.

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* H.M.S.O. 2s. 6d.

8. Tree Diseases

The Forest Pathologist has reviewed the status and effect of tree diseases in Britain. The most serious diseases under observation at the moment are diseases of pole crops, namely group-dying of Sitka Spruce, top-dying of Norway spruce, and group-dying of pines in East Anglia. The latter is due to *Fomes annosus* and has been under investigation for a number of years. The first two, which have entirely different symptoms, are due to unknown causes, no pathogen having been discovered in either case. While the Sitka spruce dying may be attributable to soil conditions, the Norway spruce disease is almost certainly not, and has all the appearance of attack by a virulent pathogen.

Other diseases causing some concern, though not so important as the above, are the debility of Corsican pine on certain sites in North England and Scotland, (not necessarily associated with *Brunchorstia destruens*) and the dying of Scots pine on calcareous soils. Of the leaf-cast diseases, only *Phaeocryptopus gäumannii* on Douglas fir, and *Lophodermium pinastri* can be considered serious.

Among the forest hardwoods, beech and ash canker diseases are mentioned, the causes in each case being not definitely known. Elm disease, a vascular wilt transmitted by bark beetles, has spread slowly over a large part of the country. The possibility of control by insecticides, and by searching for resistant varieties, is being investigated. The mode of transmission of the bacterial canker of poplar is as yet unknown, and consequently our technique for testing poplars for immunity under natural conditions is imperfect, though much useful information regarding relative immunity has been obtained. The fungus causing the disease of sycamore which started at Wanstead Park, East London, has been identified as *Cryptostroma corticale.*

9. Forest Entomology

The main activity of the Entomological section was a study of the Green Spruce Aphis (*Neomyzaphis abietina* Walker). An account is given of its life history, which is complex. There is no evidence of an egg stage; and propagation, whether from the winged or wingless females, is entirely viviparous and parthenogenetic. They are exceedingly prolific. There is no clear hibernation period, and reproduction continues in mild weather in winter. Norway spruce and Sitka spruce are the trees most susceptible to attack, but only the latter suffers complete defoliation of all except current year's shoots. Other spruces are only mildly attacked, while certain species, of which *Picea omorika* is one, appear to be almost immune. Detailed records have been made of the seasonal fluctuations of *Neomyzaphis*, caused by the weather conditions on the one hand and predators and parasites on the other.

The Large Larch Sawfly (*Pristiphora erichsonii* Hartig) survey of the previous year has been followed up. There has been a slight decrease in populations in several of the areas where it was found in 1949, but overall, the 1950 survey indicates that this pest is at the moment tending to increase over a wide range.

The Small Larch Sawfly (*Anoplonyx duplex* Lep.) outbreak at Craigvinean (Perthshire) has declined, but other infestations in this vicinity are developing. At Drumtochty Forest, Kincardineshire, several thousand of the parasite *Dahlbominus fuscipennis* Zett., have been liberated in an area of a strong infestation.

A watch is being kept on outbreaks of various other larch and spruce sawflies in different parts of the country.

A preliminary survey has started to determine what parasites of the seedfly, *Megastigmus spermotrophus* Wachtl. occur in this country. Detailed work on the life history of this pest is being done by Mr. N. W. Hussey of Edinburgh University, and is described in Part II of this report.

Collections of the Pine-shoot Tortrix, *Rhyacionia* (*Evetria*) *buoliana*, have been made at Wareham (Dorset), Rendlesham (Suffolk) and Tunstall (Suffolk), where the parasite *Copidosoma geniculatum* Dalm., which had been imported from Austria, had been released in 1936, to see whether it had survived. The Tortrix attacks had collapsed, largely due to the resident parasite population, but some individuals of *Copidosoma* were recovered from Rendlesham.

Some small scale tests with systemic insecticides on Sitka spruce were made, but not with very promising results so far. Laboratory tests on a number of insecticides for killing pine weevils and bark beetles in traps were made. The most effective insecticides have, however, repellant properties. A search is being made for an effective insecticide that does not repel, and preferably attracts the insects.

Considerable consignments of the parasite *Ibalia leucospoides* Hochw. were sent by air to New Zealand for the control of *Sirex* "wood-wasps" in the extensive new coniferous forests there.

10. Machinery Research

The Machinery Development Officer reports on progress in the following mechanical development projects:—British tractors to replace American ones, and in particular, tractors for soft ground; the development of ploughs for draining and planting, including trials of a plough mounted on a tracked tractor; trials of power-operated cableways and of aluminium chutes for the extraction of timber from hilly country, and tests of peeling machines for small diameter poles. Preliminary trials of machines for clearing derelict woodland have been made, and vehicles for haulage over various types of ground are under investigation. Tests with a self-pressurised back-pack fire extinguisher indicated the unsuitability of this type owing to the reduction in the amount of water that can be carried. Development of machines is in progress for applying formalin and various weed-killers to nursery seedbeds, and for root-pruning seedlings. For loading poles on to lorries, the Swedish H.I.A.B. power hoist has proved successful.

11. Photography

The central photographic collection now contains 4,500 photographs, and is up to date as regards printing. The titling and indexing is, however, in arrears. A great increase in orders for photographing and for prints was experienced. Experimental work was mainly on methods of colour processing, and useful new methods of producing colour prints were worked out. A certain amount of general cinematograph work was also done.

12. Library and Documentation Work

The Library now contains 1,545 books and 881 bound volumes of periodicals. A catalogue of books and periodicals in the library, and a list of the Forestry Commission publications issued from 1919 to 1950, have been printed. Documentation work is behind hand, although we now have about 26,000 reference cards.

Part II of the Report deals with work carried out by members of universities and other institutions. Financial assistance for these investigations is usually given by grants from the Forestry Fund, and in a number of cases help in carrying out field work is provided by the staff of the Forestry Commission Research Branch.

13. Sub-Committee on Nutrition Problems in Forest Nurseries

Dr. E. M. Crowther, of Rothamsted Experimental Station, reports on the work done in 1950 for this sub-committee. New experiments were laid down in six nurseries and old experiments continued there and in six other nurseries. A series of test demonstrations was established in several Conservancy nurseries. The season was characterised by good rainfall in late summer and autumn, with corresponding good growth, which brought out a number of points that had been lost in the poorer growth of the three preceding dry summers.

FERTILISERS AND COMPOSTS. Experiments confirmed that in general (17 out of 20 times) slightly larger plants were grown using fertilisers than using composts. Fertiliser-raised plants were every bit as good as compost-raised plants when planted in the forest. The long term effects of pure fertiliser and pure compost regimes of manuring are being investigated. In the oldest experiment on this at Bagley Wood Nursery, Oxford, there is no sign in the third season that the fertiliser plots are suffering from lack of organic matter.

In the matter of crop rotations, various green crops and grass leys are being tested, but it is too early yet to see any results.

Work on fertilisers in seed beds continued, and was extended to a number of different species. Sitka spruce gave the largest responses, but other species all behaved similarly, indicating that the general conclusions drawn from Sitka spruce may be applied with reasonable confidence to other common conifers. One notable result at Bagley Wood was the greatly increased response to nitrogen when both potassium and limestone were given.

In a test of a range of different pH values of the soil, (from 4.0 to 7.0) most species proved relatively insensitive to soil reaction, giving satisfactory growth over almost the whole scale. This may, however, be a seasonal effect.

Acidification of the soil in three "Sitka-sick" nurseries all gave good growth responses. Residual effects of acidification are often greater than those of formalin or steam treatment. An analysis of the results of formalin treatment suggests that the effects are more likely to be nutritional than due to any "partial sterilisation" or fungicidal effect. Other fungicides tested gave very much smaller responses.

Manuring of transplants, in three nurseries, gave good responses to different fertilisers in different nurseries. Seedling extension experiments (to the transplant lines) were mostly inconclusive, as usual; but in one case plants from seedbeds treated with formalin gained on those without, while in other cases transplants that had had nitrogen manuring in the seedbeds did better than those that had not had nitrogen.

In forest experiments, good responses to manuring at the time of planting were obtained—both to phosphorous and nitrogen fertilisers, particularly the former, but results varied according to local conditions. In experiments on the planting of seedlings direct in the forest, general observations suggested that there were marked differences in survival according to the nursery of origin. In general, casualties with seedlings were high, and results suggest that unless methods of ploughing and planting appropriate to such small plants can be developed, it may be better to give more attention to improving the production of transplants.

14. Researches in Soil Mycology

Dr. I. Levisohn of Bedford College, London University, describes the effect of mulching of various tree species with heather or bracken, on the infection of the roots with mycorrhizal or "pseudomycorrhizal" fungi. In general mulching, which produces healthier growth of better colour, is also associated with the more normal types of mycorrhizal development in the roots, to the exclusion of the reputedly harmful pseudomycorrhizas.

In old-established nurseries of the agricultural type, in which growth had fallen off, a study of pine roots showed a characteristic haustorial intracellular type of infection of the roots, the fungus of which has been isolated and cultured. It is characteristic of soils of poor general "microbial" activity, and is usually absent where a suitable mycorrhiza-forming fungus is present. These haustorial infections form pseudomycorrhizas of varying virulence.

15. Influence of Tree Growth on Soil Profile Development

Mr. T. W. Wright was appointed in succession to Dr. J. D. Ovington at the Macaulay Institute for Soil Research, Aberdeen, to carry on the work started in Culbin Forest, Morayshire. A number of new plots were laid down in plantations of different ages, and studies commenced on vertical moisture distribution, soil and air temperatures and air humidities. Chemical methods are being used to determine the intensity of podsolization and the amount of microbiological activity of soil samples in the laboratory.

16. Mineral Nutrient Studies in Heathland Plantations

Dr. L. Leyton of the Imperial Forestry Institute, Oxford, continued his investigations into the mineral nutrient status of plants of Sitka spruce and Scots pine at Clashindarroch (Aberdeenshire), and Sitka spruce and Corsican pine at Wykeham (Allerston Forest, East Yorkshire) growing on *Calluna*-dominated land. Nutrient status was based on analysis of the needles, combined with total dry needle weight. The general deduction is that the checking of Sitka spruce in heather is due primarily to a deficiency of available nitrogen. Removal of *Calluna* results in an increase in the nitrogen status, a marked increase in the amount of potassium, and a decrease of the calcium and manganese in the needles. The significance of these changes is not yet fully understood. Other studies have suggested that the nutrient status of the *Calluna* leaves may be a good indicator of site quality for Sitka spruce.

17. Research into the Physical and Chemical Properties of Forest Soils

Mr. P. J. Rennie of the Imperial Forestry Institute, Oxford, continued his investigations on the heathland types in Allerston Forest (Yorkshire) both under forest crops and in the natural *Calluna* heath. Among other results, he has shown that increase in the proportion of the smaller (clay and silt) particles is correlated with increased difficulty in afforestation. Ploughing only improves the porosity of the soil in the actual ridges, the ground beneath remaining unchanged for the full width between furrows. Tree growth—e.g., twenty year-old Sitka spruce, has greatly improved soil aeration down to a depth of 60 cms. (about two feet). The rooting habits of the trees in relation to the soil profile are also being studied.

18. Soil Fauna

Mr. P. W. Murphy of the Imperial Forestry Institute, Oxford, continued his work on the meso-fauna, mainly Oribatid and Acarid mites and Collembola on the Yorkshire heathlands. Improvements in extraction techniques have revealed much greater populations, of the order of two thousand million per acre, on natural heathland and heathland with trees, higher populations in fact than have been reported from grassland and arable land. A better knowledge of the habits and distribution of these creatures should, it is felt, have considerable practical significance in forestry operations. Culturing experiments with certain mites have given interesting preliminary indications regarding feeding habits, amount of litter consumed, and the amount and particle size of the excrement produced, as well as the breeding habits of the mites.

19. Botanical Studies of Tree Variation

Dr. E. V. Laing at Aberdeen University has continued his botanical studies into the differences between races and strains of European larch, Japanese larch and hybrid larch. Several strains can now be identified with certainty, and in the case of Japanese larch such great variation has been found that it is suspected that some trees do not belong to this species at all but are something else, possibly *Larix gmelini.*

20. Investigations on Fomes annosus in East Anglian Pine Plantations

Dr. S. D. Garrett has carried on the work commenced by Dr. J. Rishbeth, during the latter's absence from this country. Different applications to freshly cut stumps to prevent infection by *Fomes* spores were compared. It was found that ordinary oil-gloss paint was as effective as higher-quality titanium paint, and far cheaper. Tar and creosote mixture was superior to creosote alone. Infection of stumps by a spore suspension of the fungus *Peniophora gigantea,* which is antagonistic to *Fomes,* again gave successful results, but no better than the more practical method of painting, provided the latter is done immediately after felling.

21. Effect of Partial Sterilisation on the Fungal Flora of an Old Forest Nursery

At Ampthill Nursery (Bedfordshire), Dr. J. H. Warcup of Cambridge University continued his studies of the recolonisation of the upper layers of nursery soil in which almost all fungi had been killed by steaming or application of formalin solution. The re-appearance of fungi was remarkably slow, effects being marked eighteen months after treatment. *Trichoderma viride* was the dominant recoloniser on formalin-treated soil, while on steam-treated soil *Mortierella*, *Phoma* and *Coniothyrium* spp. appeared first.

The mean height and total numbers of Sitka spruce seedlings were considerably increased by the steam and formalin treatments, but it is not known how far it is due simply to release of more nutrients rather than to the killing of soil fungi.

22. Megastigmus Insects Attacking Conifer Seeds

Mr. N. W. Hussey, of Edinburgh University, examined a large range of seed samples for the occurrence of *Megastigmus* seed fly attack. *M. spermotrophus* was the commonest species in Douglas fir and silver firs, but *M. pinus* was also bred from *Abies nobilis* and *A. grandis.* A Chalcid parasite (not yet identified) was found affecting about thirty-five per cent. of *Megastigmus* larvae on the Rosehaugh Estate, Avoch, Ross-shire.

23. Nesting of Titmice in Boxes

Dr. D. Lack, of the Edward Grey Institute of Ornithology, Oxford, reports on the third year of the experiments on the nesting of titmice in bird boxes. This constitutes the largest properly observed survey of the nesting of any British species that has ever been attempted. In all, records were kept of the nests of 337 great tits, 264 blue tits, 132 coal tits and 3 willow tits, and accurate quantitative data on breeding season, average clutch size and nesting success from widely separated localities will be available. It is proposed to let the experiment run one more year before publishing a comprehensive account.

Part I. Work carried out by Forestry Commission Staff

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES
Assistant Silviculturist

The scope of the work at the Alice Holt seed laboratory was increased during 1950 to include a large number of routine seed examinations for advisory purposes on home-collected, and some imported, seed lots. In addition, experimental work on seed testing methods, seed storage, pretreatment and other problems was continued. 430 routine and 596 experimental germination tests were carried out during the year.

Application was made for a licence as a Private Seed Testing Station with a view to taking over, in 1951, routine testing of all seed lots used by the Forestry Commission. A start was made on the re-organisation of the laboratory to cope with the extra work which will be involved.

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

Tests carried out in previous years on home-collected seed lots of common conifer species have shown a disconcertingly high proportion of poorly germinating lots. In 1950, in order to avoid wasteful collections of bad seed lots, cone samples were examined for each Conservancy from stands in which large-scale cone gathering was envisaged. On receipt of each cone sample, the seeds were extracted, and purity and quick viability tests were made on the seed sample obtained. Nearly 350 cone samples were examined in this way during the season, Douglas fir, Japanese larch, Scots pine, Norway spruce and Sitka spruce being the principal species. Recommendations were made on the suitability of each stand for bulk cone collection according to the viability percentage of the seed extracted from the cone sample. In cases where it would be desirable to carry out bulk collections for special reasons, e.g. from elite stands, collection recommendations based only on seed germination quality would be ignored.

These tests showed a very large variation in the germination quality of seeds from different stands of the same species; the proportion of good to bad lots varied from one species to another. Scots pine showed the highest proportion of good seed lots, over one half of the samples examined contained more than 70 per cent. sound seed. In Corsican pine, Norway spruce, Douglas fir, Japanese larch and European larch, more than one half of the samples contained less than 30 per cent. sound seed.

The considerable variation in seed quality between stands of the same species does suggest that where possible it is desirable to make a preliminary seed examination before large-scale cone collection.

Germination Testing Methods

The experiments commenced in 1948 on embryo vital staining methods for testing tree seed viability, using 2, 3, 5 triphenyl tetrazolium bromide, were extended to include tests on five species in 1950. In 1949 it was found, for the species investigated, that the viability percentage indicated by the proportion of seed embryos stained by tetrazolium was an overestimate of total germination in a standard Copenhagen tank germinator. Accordingly, in 1950, the classification of embryo staining categories was modified, so that only those embryos strongly stained on five-sixths or more of the surface are to be considered as germinable seeds.

Results obtained with a large number of seed samples of Japanese larch, European larch, Norway spruce, Sitka spruce and Corsican pine, showed that the percentage of embryos showing strong staining over the whole surface following tetrazolium treatment, gave a close approximation to field germination per cent. under good average nursery conditions. For European larch and Corsican pine, this was found to correspond with germination after ten days in a standard Copenhagen tank germinator, and germination at twenty, thirty, and forty days respectively for Norway spruce, Japanese larch and Sitka spruce.

The great variation in soil, climatic and other factors between different nurseries, makes it impossible to provide an estimate of field germination which can be applied to all conditions. The germination test however does provide a valuable quality index for comparing one seed lot with another, and it can be used to estimate field germination if details of yields from past sowings are available for the site concerned.

The close correlation existing between the germinable seed percentage as indicated by the tetrazolium staining method and germination in a standard germinator, should prove of considerable practical value, due to the rapidity of the chemical method.

Seed Storage

The construction at the Research Station of a constant temperature room for use as a seed store, was completed during the year. The room, which has a capacity of 540 cubic feet, is maintained at a constant temperature of 36°F.

Dependence on periodic mast years for seed supplies of several hardwood species, notably oak and beech, and the difficulty of storing these species for more than a few months, makes it almost impossible to avoid plant shortages in certain years. Experiments were commenced in 1950 to study the possibility of storing oak and beech seed for more than one season without serious loss of seed viability. Experimental seed lots are being kept in store under atmospheric temperature conditions ranging from 10 to 36°F. Within each temperature condition, the importance of seed moisture content, and the use of sealed containers, is being tested. It is too early to make definite conclusions, but after seven months the evidence is that the optimal storage temperature for oak and beech seed is in the region of 30°F., with the seed stored either in moist peat or sand, or in a sealed container. Storage temperatures as low as 10°F. are highly damaging to seed of both species.

Similar tests on storage conditions are being made on seed of common conifer species. All these trials will be continued as long as a useful proportion of viable seeds remain in any treatment.

Pre-Sowing Treatments

Experiments carried out annually since 1947, to test the effect of seed soaking prior to sowing on the rate of germination and total germination of a range of conifer species, have produced completely negative results. Periods of soaking from one to thirty days were tested for seed of Sitka spruce, Norway spruce, Japanese larch and Scots pine.

Experiments during the three years prior to 1950 indicated that, while there was occasionally a slight increase in the rate of germination following soaking, the practical advantages were small, and the effect on final germination quite negligible. In the 1950 repetition of this experiment, regular seed bed watering was included as a treatment. The results obtained confirmed the conclusion made from work up to 1949, that the low response to seed soaking does not appear to be altered in any way by seasonal differences, or differences in the soil moisture conditions in the seed bed during the season.

EXPERIMENTAL WORK IN NURSERIES

By R. FAULKNER and G. D. HOLMES
Assistant Silviculturists

Partial Soil Sterilisation

Formalin and Steam

At Ampthill an experiment on Sitka spruce was designed to compare the effects of formalin with steam sterilization using the "Hoddesdon Grid", "Harrow", and "Canopy" or "Hood" apparatus. Final results indicated that steaming produces greater height growth than formalin treatments. Of the three steaming treatments, the "Hoddesdon Grid" (a steam header pipe with several one-inch perforated iron tubes 9 to 12 inches apart built into the form of a comb) was slightly more effective than the other two treatments.

The 1948 sterilization experiment, designed to compare steam and formalin on areas treated with and without organic manure, nitrogen, and a combined dressing of potash and phosphate, was started at Tulliallan, Fife, using compost as the organic additive. Results showed that both steam and formalin significantly increased mean heights. Although the height differences for formalin were small, they are of interest because previous formalin sterilization results at Tulliallan have been insignificant. Steaming reduced weeding times from 13.9 minutes per square yard to 3.6 minutes. The effect of formalin on weeding times was unusual, in that formalin treated plots took 1.3 minutes longer to weed than untreated plots.

Interactions between steam and inorganic phosphate and potash fertilizers produced a significant mean height increase of 0.36 inches. Formalin and inorganic fertilizers produced no significant interaction results, but formalin and compost produced a significant height increase of 0.25 inches.

Residual Effects on Second Year Sowings

The 1949 Hoddesdon pipe experiment at Newton, Morayshire, was resown. This experiment was designed to show the effectiveness of steaming (controlled at 25 lb. per sq. inch pressure at the inlet manifold) for periods of 10, 15 and 20 minutes on soils artificially brought to three different moisture levels.

Results indicated that the twenty minute steaming treatments produced the tallest spruce (although these were only 0.20 inches taller than seedlings on untreated plots), and at the same time had the greatest reducing effect on weeding times. Although the ten minute sterilization treatment produced no increase in mean heights when compared with control plots, the weeding times were reduced by more than half. Therefore it can be concluded that at Newton the main second year benefit of steaming is the continuation of reduced weed growth, any increased height benefit being negligible.

The interaction of sterilization and different initial moisture levels produced no conclusive differences in the second year.

At Ampthill, the 1949 experiment comparing the effects of steam and formalin on the growth of Sitka spruce was continued into its second year. Results showed that both steam and formalin had appreciable residual effects upon height growth and total numbers of second year seedlings, steam being slightly better of the two. First year seedlings lined out on their plots of origin showed little variation in survival, but formalin produced slightly taller transplants than the steam. Resown plots indicated that steam had a greater residual effect upon total numbers and height growth than the formalin. Both formalin and steam treatments produced much better plants than the untreated ground.

Residual Effects on Third Year Sowings

At Newton, and Benmore, Argyll, where sterilization had been effective in 1948, the original plots were resown for a second time. Steam treated plots produced seedlings only very slightly taller than untreated plots, (see Table 1) whereas the formalin treated areas produced slightly larger seedlings than the steam sterilized plots. Steam and formalin both increased the total numbers of seedlings. Weeding times were reduced on the steamed plots (markedly so at Benmore) whereas formalin produced only a small reduction in weeding times at both nurseries.

HEIGHT GROWTH, YIELD AND WEEDING TIMES FOR ONE-YEAR-OLD SEEDLINGS OF SITKA SPRUCE SOWN ON PLOTS STERILIZED THREE YEARS PREVIOUSLY

Table 1 (Experiment Group 48(C) P.50 Extension)

Treatment	Mean Heights (inches)		Total Numbers per sq. ft.		Total Weeding Times per sq. yd. (mins.)	
	Newton	Benmore	Newton	Benmore	Newton	Benmore
Unsterilized plots....	1.33	0.60	67	76	13.5	9.9
Steam sterilized	1.36	0.69	77	87	12.9	4.8
Formalin sterilized	1.42	0.70	81	83	13.2	7.5

This shows that the residual effect of formalin on height growth is slightly greater than that of steam, but that steam has the greatest residual effect upon weed control. Both forms of sterilization appreciably increase the total numbers of seedlings. The figures are averages for plots receiving various combinations of manures and in some cases no manures at all.

Field Extensions

A nursery extension experiment was conducted at Gwydyr Forest, Caernarvonshire, with the object of comparing the growth and survival of one year Sitka spruce seedlings raised on steam or formalin sterilized ground, when planted in the forest. As in previous Scottish experiments of this nature, it was found that at the end of the first growing season in the forest there were no significant differences in mean height increment or survival between plants raised on sterilized or unsterilized soil. There was no significant regression between final and initial heights.

Formalin Sterilization

A preliminary experiment was laid down at five nurseries to test the effects of formalin as a soil sterilizing agent when applied in solutions equivalent to 0.1 gallons and 0.05 gallons of 40% formaldehyde per square yard, when applied at time intervals of 5 days, 10 days and 15 days prior to sowing, and using "Sisalkraft" paper or water as soil sealing agents. Sitka spruce was used as the indicator species.

Resulting from these preliminary trials, it appears that the time of sterilization (within the limits specified) and method of soil sealing have little effect upon seedling heights, total numbers of plants or weeding times; furthermore only small effects upon mean heights, total numbers or weeding times, were observed between the two different concentrations of formalin.

"D-D" Soil Fumigant

"D-D" soil fumigant (a mixture of 1, 3 dichloropropane and 1, 2 dichloropropane) was used to test its efficacy as a soil sterilising agent. Three concentrations of 150 lb., 300 lb. and 600 lb. per acre were tried and injected to a depth of six inches and sealed into the soil by water or soil compaction. The effect of the fumigant on germination, stocking and height growth of Sitka spruce seedlings was compared with seedlings growing on plots treated with the standard formalin solution, and with untreated plots. The experiment was conducted at Newton, Benmore, Inchnacardoch, Fleet and Tulliallan nurseries.

"D-D" reduced the rate of germination in the early part of the year, but by mid-July this depressing effect had largely disappeared. The reductions were approximately in direct proportion to the concentration of the "D-D" in the soil. Formalin also produced a marked depressing effect on germination in the earlier stages of germination, at three of the five nurseries. At two nurseries sealings by compaction increased the preliminary germination, although the difference between sealing by compaction and by water gradually disappeared as the season progressed.

Final results taken at the end of the growing season showed that there were no significant differences between the three levels of "D-D" for mean heights or total numbers except at Benmore where the 600 lb. of "D-D" per acre reduced the stocking by fourteen plants per square foot. Formalin had the greatest beneficial effect upon mean heights and total numbers (see Table 2), except at Inchnacardoch and Tulliallan, where it slightly reduced the total numbers in comparison with "D-D" fumigant. It must be noted that the stocking on all plots at Tulliallan was extremely low, and some other factor may be the cause of this erratic result.

HEIGHT GROWTH, YIELD AND WEEDING TIMES FOR ONE-YEAR-OLD SEEDLINGS OF SITKA SPRUCE ON GROUND RECEIVING VARIOUS STERILISATION TREATMENTS AT SEVERAL NURSERIES

Table 2

Nursery	Mean Height (inches)			Total Number per sq. ft.			Weeding Times Minutes per sq. yd.		
	D.D.	Formalin	Control	D.D.	Formalin	Control	D.D.	Formalin	Control
Inchnacardoch	0.62	0.72	0.50	90	81	96	6.0	3.3	6.9
Benmore....	0.58	0.68	0.52	77	82	91	8.5	6.2	12.5
Fleet	0.84	1.43	0.80	64	72	66	8.9	8.6	10.8
Newton	0.61	0.85	0.56	46	57	53	—	—	—
Tulliallan	1.02	0.92	0.93	32	27	28	—	—	—

The first year results show that "D-D" has a sterilizing action upon the soil. It produces slightly taller but fewer seedlings than untreated ground, and it slightly reduces the weed growth. In comparison with formalin it is less effective in all respects, but this may be due in part to the technique of application.

In 1951 further trials will take place in which the fumigant will be injected into the soil at a depth of four inches, and greater precautions will be taken to ensure that all residual vapours are removed from the soil before seed is sown.

Acidification of the soil

The plots used in the 1948 acidification and sterilization experiment at Newton Nursery were resown for the third year without further treatment.

None of the residual acidification treatments significantly increased or reduced the stocking of seedlings, but all had a marked beneficial effect upon the height growth of the Sitka spruce seedlings, with the single exception of the two-ounce level of sulphur per square yard. Acidification with heavy applications of ammonium sulphate (1 lb. per square yard) yielded the best results, with the six-ounce and four-ounce dressings of flowers of sulphur per square yard and sulphuric acid (1 gallon of 4% solution per square yard) following in that order. The effects of partial soil sterilization by formalin were insignificant in the third year.

A repetition of the 1948 acidification and sterilization experiment was started at Widehaugh, on a site where the pH value was above 7.5 and which had a soluble lime content of 0.92%. In this case there was no significant beneficial or adverse effects of any of the acidifying agents. The formalin sterilization had a marked beneficial effect on mean heights and total numbers, and it highly significantly reduced weeding times.

This result is comparable to results obtained in previous years at some other nurseries, where, in spite of a high initial pH value, the addition of acidifying agents had insignificant effects. Because of this it is assumed that alien factors, unaffected by acidification but discouraged by partial sterilization, are retarding the growth of Sitka spruce seedlings.

Manuring

Placement of Fertilizers

An experiment containing five of the 1949 treatments, and three new treatments, was repeated at five nurseries on sterilized ground. It was designed to compare the effect of placed N, P and K fertilizers in selected combinations drilled below the seed, with the standard method of broadcasting seed and fertilizers. Both organic and inorganic forms of nitrogen were used.

In all cases the treatments in which both seed and fertilizers were drilled produced the tallest seedlings of the Sitka spruce.

Flash (waste urea-formaldehyde plastic) in various combinations with potash and phosphate, drilled or broadcast, with drilled seed, invariably proved to be the superior treatment. Differences between nitrochalk, applied as two top dressings or as one basal and two top dressings, were only slight, but the overall advantage showed that the three-application treatment was slightly better.

It was found, as in last year's work, that drilling of seed slightly reduced the total number of seedlings per square foot, but the reduction at Wauchope and Inchnacardoch was very marked.

On the basis of the 1950 experiments it is concluded that at most nurseries drilled fertilizers at standard rates, with "flash" as the source of nitrogen, definitely give a marked increase in height growth. This height growth, however, was not sufficiently large to produce more than 60% usable plants; and this fact, coupled with a marked reduction in the number of seedlings per pound of seed, in no way indicates that drilling seed above placed fertilizers should replace broadcasting both seed and fertilizers.

THe experiment is being repeated in 1951 and is to include additional new combinations of drilling and sowing both seed and fertilizers.

Forms of Applying Nitrogen to Seedbeds

A repetition of the 1949 experiment confirmed the first year's results in which the plastics, i.e. flash (formaldehyde plastic waste), formalised casein, and in 1950 a mixture of hoof meal and formalised casein also, produced the tallest and greatest number of seedlings at the majority of nurseries. Hoof-and-horn meal also produced a marked increase in height growth. Vegetable meal and fish guano both had a marked depressing effect upon height growth, except at Benmore where vegetable meal was the optimum treatment in this respect. In comparison with inorganic nitrogen applications (nitrochalk applied as two top dressings) the plastics produced taller seedlings, although the final stock of seedlings was less.

Germination assessments were conducted during early spring, and these showed that all organic forms of nitrogen depress both the rate and amount of germination. The plastics have the least effect, with hoof and horn meal, vegetable meal, and fish guano normally following in that order.

Second Year residual effects

The individual plots of the 1949 experiments were split. One third was allowed to continue growing for a second season, half was resown without addition of any organic nitrogen manures, and the remaining portion was left as a central buffer strip. The flash-treated plots on the whole produced the tallest one-year seedlings, but at three nurseries the residual effect of the vegetable meal produced the tallest seedlings. Formalised casein, hoof-and-horn meal, and fish guano had little or no residual beneficial effects upon height growth, and no treatment had any marked effect upon the total numbers of seedlings.

The two year old spruce treated with flash and formalised casein maintained the lead gained during the first year, and at three nurseries vegetable meal treated plots made very good height growth, although on these plots the total numbers of seedlings was very much less following the heavy reduction in germination during the first year. Total numbers per treatment followed the same ratios as in 1949.

Organic and Inorganic Manuring in Heathland Nurseries

The greencropping experiment designed to ascertain whether initial applications of compost can be replaced by a suitable greencrop and inorganic fertilizers, which was started in 1949 at Littleburn Nursery (Kilcoy Forest), Roseisle, and Devilla heathland nurseries, was continued into the second year. Unfortunately, due to heavy "cut-worm" attacks at Devilla, and a rapid invasion of sorrel (*Rumex* spp.) at Roseisle, these two experiments had to be abandoned. Littleburn nursery suffered no similar interference, and the main conclusion drawn at the end of the first growing season was that the effect of the ploughed-in greencrop, when compared with composted areas, was to increase the overall mean heights of Sitka spruce by 0.17 inches.

In combination with the standard dressing of phosphate and potash, the compost and the greencrop behaved in very different ways. Phosphate and potash, at standard rates on the greencropped areas, produced seedlings averaging 1.72 inches in height; the combination had no significant beneficial or detrimental effect upon total numbers. Phosphate and potash, applied at standard rates in the presence of the compost, produced seedling heights of only 1.39 inches, and in addition reduced the stocking. (This reduction in numbers and height growth may be due to the mild drought conditions in early spring which would be accentuated on the compost treated plots.) In comparison with results of previous years, reductions in size and numbers were observed to be general on the majority of heathland nurseries in 1950.

The overall effect of applying the standard amount of nitrochalk as two top dressings, was to increase height increment by 0.5 inches, and when applied as one third basal dressing, with the remainder of the manure applied as two top dressings, the height increase was 0.4 inches. Similarly the overall effect of adding standard rates of phosphate and potash fertilizers was to increase mean heights by 0.7 inches.

Composting and Trials of Compost

The long-term composting and fertility maintenance demonstration at Wareham Heathland Nursery, Dorset, was continued. A large variety of conifer and hardwood species was raised, and yields on composted sections were high. The importance of breaking up iron pan formations in heathland nursery soils was well shown at Wareham in 1950. Growth on sections which had not been subsoiled since the nursery started in 1945, showed very poor growth of all species in spite of heavy compost dressings.

An experiment was started at Wareham to test the beneficial effects obtained following the late Dr. M. C. Rayner's technique of applying a bracken mulch to composted ground in the summer prior to cropping. This trial, which compares bracken mulch with an inert cellulose mulch, is being made to determine how far the mulching effect is physical or nutritional, and to study soil microbiological changes following treatment.

Trials of Compost and Organic Manures

Nursery trials were laid down at two centres to test experimental composts prepared during 1949, using sawdust, straw and heather base materials. None of the sawdust composts tested had any appreciable effect on the growth of Sitka spruce seedlings, though in most cases there was a slight increase in seedling yield following treatment. All straw composts increased seedling growth considerably at both centres. Heather composts gave disappointing results on heathland soils, but gave good increases of seedling growth and yield when applied to a woodland nursery soil.

There was little difference in manurial value between composts of the same base material prepared with different activators. In general, composts prepared with poultry manure, guano or sewage sludge gave better results than all others.

Trials were conducted in 1949-50 to examine the manurial value of slaughter-house blood as a direct soil application, both alone, and in combination with bracken, prior to cropping the ground with seedlings. These treatments were tested as autumn and spring applications, in comparison with bracken and blood compost prepared in the normal manner.

Autumn application of blood to the soil at the rate of 4,500 gallons per acre considerably increased the growth of one-year seedlings of Sitka spruce during the following season. The growth improvement obtained was equal to that following application of bracken/blood or bracken/hops compost at twenty tons per acre. In all cases direct blood applications reduced seedling yields to some extent. Blood treatment shortly before seedbed preparation in spring caused serious reduction of seedling yields, and growth increases were negligible. Compost treatment in spring resulted in some reduction of yield, but gave better growth increases than any other treatments, including application of compost at the same rate in the autumn.

Composting methods

An attempt was made to produce adequate breakdown of wheat straw, and sawdust, using synthetic nitrogenous materials as activators in place of the more commonly used organic activators, such as hopwaste or dried blood.

An excellent straw compost can be prepared by the addition of 40 per cent. by volume of hopwaste to the heap. Little success was obtained with ammonium sulphate, but the addition of ground limestone appeared to assist the process of decomposition, though the final compost obtained using these materials alone was not satisfactory. The incorporation of 15 per cent. by volume of succulent material such as grass mowings, to the heap at the time of preparation, greatly improved breakdown, and extended the period of high composting temperatures. The addition of grass mowings alone, without a nitrogenous activator, is insufficient to produce adequate decomposition.

Trials with formalised casein (ground button waste), as an activator for composting straw were most successful. The final compost was dark and amorphous and quite as good as the best straw and hops compost.

It is apparent from this, and previous years' work, that the three main requirements for satisfactory breakdown of straw are, the maintenance of the heap in a uniform moist condition, prevention of acid conditions, and the provision of nitrogen in a form that is slowly available. The last is the most difficult requirement to meet, as at present there is no cheap and plentiful synthetic material which can serve as a slow source of nitrogen. Formalised casein has proved good, but it is expensive and can only be obtained in limited quantities.

Satisfactory straw composts can be prepared using ammonium sulphate or nitro-chalk, providing a moisture retainer is added, and acid conditions are prevented. Sawdust has proved a most difficult material to compost, and efforts to compost fresh mixed conifer and hardwood sawdust in 1950 were not successful. Heaps consisting of sawdust with up to 40 per cent. of added hopwaste showed only limited breakdown, and the use of inorganic activators such as ammonium sulphate was quite ineffective. Poultry manure or formalised casein produced better decomposition, but in these cases also, the compost at the end of the season was unsatisfactory. From the trials made with sawdust during 1949 and 1950 it seems clear that satisfactory compost cannot be made in a single season with existing methods, and it may be necessary to resort to a minimum two-year composting period for this material.

Grass Leys and Greencropping

The experiment commenced at Kennington nursery, Oxford, in 1947, to test the value of grass and clover ley for improving soil fertility, was continued. The soil was cropped with conifers annually prior to 1947, and was beginning to show symptoms of conifer sickness, including low responses to manurial treatments.

Results to the end of 1950 show no improvement in general soil fertility following ley treatment. Plots which were maintained under a continuous two-year ley of perennial rye grass and white clover during 1947 and 1948 showed no better growth of transplants of Sitka spruce, in 1949, than the plots which had been fallowed or cropped with conifer transplants since 1947. Similarly, one-year Sitka spruce seedlings raised on the various plots in 1950 showed no response to 1947 and 1948 greencropping treatments.

Application of formalin solution as a partial soil sterilization treatment prior to seedbed preparation in 1950 more than doubled seedling growth on all plots, including those previously greencropped, but the response to inorganic fertilizers applied in 1950 was negligible. Compost application also gave negligible growth increases, except when applied to plots which had been fallowed or cropped with transplants and unmanured since 1947. In these cases, compost improved seedling growth considerably, except when applied to ground which had received partial sterilization treatment.

Seed-bed Covering Media

An experiment was conducted at the majority of northern nurseries where Research Branch experiments were in progress, to find out whether the many varieties of local covering media have deleterious effects upon the stocking and height growth of Sitka spruce seedlings. Table 3 indicates the results obtained at specific nurseries. Wherever nursery soil was used as a cover, the resulting crop of seedlings was always of very inferior quality and density, and frost lift during the following winter was most severe. The ground in this group of experiments was not sterilized, with exception of Benmore where the soil was partially sterilized with formalin.

HEIGHT GROWTH AND YIELD OF ONE-YEAR-OLD SITKA SPRUCE SEEDLINGS, SEEDS COVERED WITH VARIOUS MEDIA AT DIFFERENT NURSERIES

Table 3 (Assessments made in late autumn 1950)

Nursery	Covering Media	Mean Height (inches)	Total Numbers per square foot
Mabie, Kirkcudbright	Carlops No. 4 sand	1.11	44
	Formalin sterilized nursery soil	0.84	10
	Nursery soil (unsterilized)	0.74	10
	Locharbriggs grit*	0.88	27
Royal Botanic Garden, Edinburgh	Thankerton grit	0.80	23
	Soil	0.73	15
	Carlops No. 4 sand	0.76	40
Inchnacardoch, Inverness .... (Established Nursery)	Speymouth grit	0.90	60
	Loch Lochy grit*	0.70	65
Inchnacardoch, Inverness .... (Heathland Nursery)	Speymouth grit	0.87	70
	Loch Lochy grit*	0.70	45
Tulliallan, Fife	Thankerton grit	0.42	88
	Soil	0.38	57
	Wormit grit*	0.43	77
Fleet, Kirkcudbright	Local sand*	0.95	65
	Soil	0.80	58
	Carlops No. 4 sand	0.95	70
Benmore, Argyll	Carlops No. 4 sand	1.32	90
	Loch Eck grit*	1.27	78
Wauchope, Roxburgh	Doncaster quartzite	1.07	69
	Carlops No. 4 sand	0.91	56
	Whinstone chips*....	0.72	22

* = Covering normally used by Conservancy

The above table indicates that in the majority of nurseries, provided that local soil is not used, one of the covering media tested is quite as good as another. Possible exceptions are Inchnacardoch (Heathland) where Loch Lochy grit is used, and at Wauchope where whinstone chips are used.

The experiment is being repeated in 1951 on formalin sterilized ground.

Seed-bed Watering and Irrigation

A small-scale seedbed irrigation trial was carried out during 1950 at Kennington Nursery, Oxford. An overhead sprayline sprinkler system was used to test two contrasting watering regimes in their effect on the growth and production of seedlings of several species. The two irrigation treatments were—

1. Application of 0.5 inches of irrigation water whenever the soil moisture deficit reached 0.5 inches.
2. Application of 1.5 inches of irrigation water whenever the soil moisture deficit reached 1.5 inches.

The rainfall during the period of the trial was well above the average for the nursery, and frequent irrigation was not necessary (vide Table 4).

RAINFALL, AND IRRIGATION WATER APPLICATIONS, JUNE-SEPTEMBER, 1950

Table 4

Month	Average Rainfall For Nursery (inches)	1950 Rainfall (inches)	Irrigation Water Applied (ins.)	
			Treatment 1	Treatment 2
June	1.8	1.52	2.73	1.26
July	2.6	4.07	—	—
August	2.0	3.14	1.70	1.56
September	2.2	3.25	0.90	—
TOTAL	8.60	11.98	5.33	2.82

The high rainfall during the growing season, together with fairly high atmospheric temperatures, resulted in vigorous growth and good survival of young seedlings of most species sown, irrespective of whether the beds received irrigation treatment. The effect of watering was quite negligible on beds of Corsican pine, Japanese larch, Douglas fir, and *Tsuga heterophylla.* Sitka spruce beds however showed a marked improvement in growth and production following treatment.

THE EFFECT OF IRRIGATION TREATMENT ON PRODUCTION AND GROWTH OF ONE-YEAR SEEDLINGS OF SITKA SPRUCE

Table 5

Treatment	Seedling Production per lb. of seed sown	Seedling Mean Height at end of season (inches)
Control	10,800	1.56
1	28,200	2,52
2	24,100	2.35

Watering produced its greatest response when applied to beds which had received basal NPK fertiliser dressings prior to sowing. Increased leaching and plant uptake of soil nutrients following watering make it important that watered plots receive full manurial applications.

Concurrently with this new trial, the hand watering experiments on rising one-year seedlings, described in the last report, were continued. This experiment is now in its fifth year, and it was continued in order to provide a measure by which to judge the responses to overhead irrigation. The essential difference between the two trials lies in the speed at which water is applied. With the overhead sprayline it takes approximately four hours to apply 0.5 inches of water, (2 gallons per square yard), whereas this can be applied in a few minutes by hand watering. In the hand watering trials water was applied whenever the surface layers of the soil became visibly dry to a depth of one half inch. This required the application of 5 inches (23 gallons of water per square yard) over the season between May and September, 1950. Because of the moist season this quantity was only one third the amount required in a similar trial during the dry season of 1949.

Rising one year seedlings of Sitka spruce, Douglas fir, Japanese larch and *Tsuga heterophylla* showed negligible growth responses to watering, and it is of interest to compare this result for Sitka spruce with the results in 1949, when the outturn of usable seedlings was doubled following watering treatment.

Low responses to watering, whether applied by hand methods or spraylines, are to be expected in a year such as 1950, with a high, well-distributed rainfall during the growing season. In most seasons in this country there are periods of drought which last long enough to check the growth of tree seedlings, and occasionally during the long droughts the provision of artificial watering may mean the difference between success or failure of the crop.

The growth effects following application of similar volumes of water by sprayline or hand methods cannot be strictly compared, due to high drainage losses following rapid application of fairly high volumes by hand methods, but the results obtained with Sitka spruce in 1950 do indicate that, as for agricultural crops, the slow application of water in the form of a spray is the best method.

In March, 1950, sample plants from the 1949 watering experiments were lined out to test residual effects. In all cases plants which had received compost and water in the seedling stage retained their superiority in size over plants from other treatments after one year in the transplant lines.

Chemical Control of Weeds in Nursery Seedbeds

Following on the promising weed kills obtained with a "white spirit" mineral oil in 1949, an extensive series of new experiments was carried out at two nurseries in Southern England in 1950. The object of the experiments was to test a range of fortified and unfortified mineral oils for the control of annual weeds in seedbeds. The four main types of compound tested were vaporising oil, white spirit, high aromatic oil, and mineral oil fortified with pentachlorphenol (PCP), or di-nitro-orthocresol (DNOC). All treatments were applied as sprays to the beds, at application rates from 25 to 100 gallons per acre (i.e. 25 to 100 ml. per square yard).

Application of these treatments as pre-emergence sprays, four to five days before the tree crop germinates, indicated that a 90 to 100% kill of weeds is possible, without appreciable damage to the tree crop of Sitka spruce or Corsican pine. An important observation in these experiments was that the first flush of weed germination represented a large proportion of total weed germination over the whole season. As a result, oil sprays applied early, when the weeds were mostly in the cotyledon stage, reduced the amount of hand-weeding required throughout the season by 90 to 95%.

A number of the oils, notably diesel oil, high aromatic oil, and oils fortified with PCP or DNOC, caused a considerable reduction in the number of tree seedlings emerging. The lighter, unfortified oils, such as vaporising oil, or white spirit, applied at volumes up to 100 ml. per square yard, are the most suitable for pre-emergence spraying, as they give almost complete kill of weeds with no appreciable damage to the tree crop.

A number of experiments were designed to test the selective properties of mineral oils when applied as post-emergence sprays to the mixed crop of trees and weed seedlings. Both vaporising oils and white spirits gave good weed control, the number of weeds killed increasing with the application rate in each case. Vaporising oil appears to be slightly more toxic. The rate of application required to kill 90% of weeds was between 55 and 60 ml., per square yard for vaporising oil, and between 60 and 70 ml. for white spirit.

The weed population controlled by these treatments was heavy. Untreated plots required a total hand-weeding time over the whole season of 50 man-minutes per square yard of seedbed, compared with an average of 2 to 4 man-minutes per square yard for treated plots. Weed species varied in their susceptibility to oil spraying. *Sonchus oleraceus* and *Trifolium campestre* were the most resistant species encountered, while other species, notably *Poa annua* and *Senecio vulgaris*, were almost completely eradicated by single applications of white spirit or vaporising oil at 50 ml. per square yard. Where the weed population includes resistant species, oil spraying cannot entirely eliminate hand-weeding. However, as the resistant weeds are usually small in number, it is a relatively simple matter to remove these by hand shortly after spraying.

The damage to rising one-year seedlings of Corsican pine was slight. After three oil applications during May and June, there was no difference in the final mean height of treated and untreated tree seedlings, though these same treatments reduced the number of weeds to negligible proportions by the end of the season. Sitka spruce however appears more sensitive, and all oil treatments damaged the seedlings to some extent. Application of vaporising oil, at 40 ml. per square yard, or white spirit at 60 ml. per square yard, caused slight damage to Sitka seedlings, and these rates should give 70 to 80% kill of weeds. Higher weed kills can be expected if the weeds are sprayed during the cotyledon stage.

These experiments have demonstrated that by using light mineral oils as sprays, weeds can be controlled in seedbeds of various conifer species. Where weeds germinate before the tree seeds, these oils, applied as pre-emergence sprays, give very satisfactory results, as they leave no residues in the soil. They may also be used for post-emergence spraying, as some conifers are relatively resistant to their toxic action. White spirits in general cause less damage to tree seedlings and appear safer than most vaporising oils.

Pines possess the highest degree of resistance to oils. Spruces are more susceptible. Douglas fir and Japanese larch appear too susceptible to permit post-emergence spraying to be used.

Damage to the tree crop following post-emergence spraying can be minimised by spraying the weed crop during the cotyledon stage, when dosages as low as 40 ml. per square yard of white spirit can give high weed kills.

These experiments are being continued and extended in 1951 to include large plot trials on a number of species in several nurseries in different parts of the country, where weed infestation is likely to prove serious.

Season and Date of Lining-out

An experiment commenced in eight nurseries (five northern, three southern) in 1949, tests the extension of the lining-out season to the late summer and early autumn months of August, September and October. Late autumn, winter and spring periods are included also.

The plants used in 1949 were one-year (or rising one-year) seedlings of Norway spruce and Sitka spruce at all nurseries, Japanese larch being used in one northern and all southern nurseries, and Scots pine and Corsican pine confined to northern and southern nurseries respectively. All seedlings were separated into height classes on lining out, in order to study the size factor in survival.

So far, one season's results only have been examined. The experiment will continue, and only the main features of the first season's work will be mentioned.

No attempt will be made to say what is, or is not, a "satisfactory" period for lining out, and the following remarks relate only to the broad effects on survival, not to the production of usable stock.

(1) Survival was extremely low in all species in all nurseries for the late summer-early autumn period, except for the two wettest localities—Benmore and Inchnacardoch. Here survivals of the order of 80% were obtained for all species, larches and Scots pine being the most successful.

(2) In the South survival of all species (except Corsican pine) was high for the period late September to mid-March.
(3) In the north the best period occurred later—late February to mid-April.
(4) High survival figures for Corsican pine in the three southern nurseries were obtained at the periods mid-December and mid-March.
(5) Whatever the species or season of lining out, survival tended to be higher the larger the seedling.

NATURAL REGENERATION OF SCOTS PINE WOODS IN THE HIGHLANDS

By J. A. B. MACDONALD
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There are good reasons, in part sentimental, for leaving the regeneration of the remnants of the old Caledonian Forest to nature. The interested public reasonably expects our natural Scots pine to regenerate themselves without much difficulty, having continued to do so down the centuries.

Officers of the Forestry Commission with such remnants under their charge, however, were not long in realising that easy natural regeneration was something of a myth—especially towards the North-West of Scotland where rainfall was moderate to high. The reasons for this difficulty were obscure to begin with, but as a result of Research Branch investigations, supported by observations of ecologists such as Dr. Fraser Darling, the obstacles to easy natural regeneration have become more apparent.

QUEEN'S FOREST, GLEN MORE, INVERNESS-SHIRE (Expt. 10. 1930) To investigate these difficulties the Research Branch was provided first of all with twelve acres of old native Scots pine in 1930. The forest lies about six miles east of Aviemore, Inverness-shire, and the site was a level one at 1,000 feet above the sea. After fencing to exclude deer, rabbits and hares, the area was carefully charted, the chart including the position of each of the parent trees. When enclosed there was a 50% to 80% stocking of old, wide crowned trees; dense, short heather occupied the more open spaces, but bilberry was dominant under many of the trees. A peaty raw humus layer, three to four inches deep, was general over the usual leached horizon and irregular "panny" line; below was a great depth of the fluvio-glacial gravel common on Speyside.

The area was divided up into tenth-acre plots, following a working plan by Dr. M. L. Anderson, and subjected to several ground treatments, viz., untreated controls; covered with dense layer of brushwood and pulled heather; brushwood and heather piled and the piles burnt to ashes; dug-over strips and patches. Other sections were to have been muir-burnt in the ordinary way, but this had to be postponed because of difficult or dangerous conditions for burning.

The first assessment, made in 1933, found no seedlings in any of the untreated sections, it being noted then that the raw humus appeared to be the main cause of failure. The areas covered with brush and heather (unburnt) also contained no seedlings; those spots on which brushwood piles had been burnt supported a very few seedlings; but the best results, though still unsatisfactory, were on the dug-over strips and patches.

In 1935 a fairly heavy crop of cones appeared on the mother trees and, anticipating a good seed fall, parts of the experimental area were re-treated by digging, etc. A second attempt had been made in 1933 to burn the heather where required by the plan, but again there were difficulties and the results unsatisfactory. Seedling counts made in May, 1938, showed very successful germination of seedlings in re-cultivated strips and patches. Although the germination in certain plots ran into thousands per acre, practically no seedlings were found in the untreated control or in the units where slash was heaped on the ground and left unburnt:—

NUMBERS OF SELF-SOWN SCOTS PINE SEEDLINGS PER ACRE UNDER VARIOUS TREATMENTS 1930 AND 1936

Table 6 Assessed May, 1938 To nearest 100

Treatment	Plots treated in 1930	Plots re-treated in 1936
A. Control—No treatment	Nil	Nil
B. Slash etc. heaped over area	Nil	Nil
C. 2½ ft. strips dug over 3 ft. apart	600	5,300
D. Patches 6 ft. x 6 ft. dug over 15 ft. apart	300	3,600
E. Patches 6 ft. x 6 ft. heaped with slash and burnt	700	—
G. "Ploughed" strips, as C	400	6,000
H. Area burnt with blowlamp	Nil	Nil
J. Area burnt and later ploughed in strips as G.	800	8,900

The 1938 growing season itself produced a heavy crop of cones, and again it was decided to repeat some of the soil cultivations before the seed fell in the spring of 1939. Subsequently a count of the seedlings was made in the early summer of 1943, and the following table shows the estimated numbers per acre on the cultivated treatments, the uncultivated sections showing no improvement since last assessed:

NUMBER OF SELF-SOWN SCOTS PINE SEEDLINGS PER ACRE UNDER VARIOUS TREATMENTS 1936 AND 1939

Table 7 Assessed Summer 1943 To nearest 100

Treatment	Treated 1930	Re-treated 1936	Re-treated 1939
C. Dug strips	200	900	700
D. ,, patches	100	600	400
G. Ploughed strips	100	2,200	700
J. Burned—ploughed strips	600	2,200	700
Average	200	1,500	600

The 1936 cultivation had produced the highest number of seedlings and the 1939 re-cultivated plots a relatively poor germination. The most vigorous seedlings were on the 1936 re-cultivations (from 4 to 18 inches), seedlings on the original 1930 cultivations being little if any larger. Interesting observations were that practically no seedlings occurred where mineral soil had been exposed; more seedlings were found in wide gaps between the parent trees, and obviously better results would have been obtained had the stocking of parent trees been reduced prior to cultivation. The experiment was examined once again in November, 1948. There were still few seedlings to be seen at all on the control and uncultivated plots, but fair numbers were beginning to show up through the strong heather and *Vaccinium* on the strips and patches which had once been cultivated. Exceedingly slow rate of development of the natural seedlings has been observed. It is also important to realise that the number of seedlings which germinate is apt to be misleading, as there are subsequently very heavy losses—due to frost lift, insect damage, and damage by black-game and capercaillie.

The best hope obviously lies in cultivation, and in view of this, and of the excellent seed fall to be expected in March, 1950, a trial was made of a tractor drawn disc-plough in an area adjacent to this experiment. A rough and not entirely satisfactory job was made, and the first germination survey made in November, 1950, revealed no natural seedlings on the ploughing.

QUEEN'S FOREST, GLEN MORE, INVERNESS-SHIRE. (Expt. 12. 1947) Experiments carried out by 1947 by Gustaf Kolmodin in Sweden and others had shown that regeneration of conifers by seeding could be stimulated considerably by killing the heather and bilberry by applications of sodium chlorate. In that year therefore a small trial was laid down, alongside the original experiment, to study the effects of sodium chlorate upon strong *Calluna* and *Vaccinium* growth, and the subsequent effect upon natural regeneration in this old Scots pine woodland. Rates from 50-250 lb. per acre were applied dry or in solution, and each section contained both an unworked and a dug-over treatment. When seen in November of that year a number of Scots pine seedlings were coming in on all the cultivated units, but a thorough search found no seedlings growing on the uncultivated ground, although the heather had been killed by the chlorate.

GLEN GARRY FOREST, INVERNESS-SHIRE. (Expt. 1. 1930.) Towards the end of the nineteen-twenties, arrangements were made with Messrs. Jones of Larbert, Timber Merchants, who were felling an area of rather nice and by no means over-mature natural Scots pine in the Stag Wood, Glen Garry, Inverness-shire, to leave a number of stems standing as seed trees. The tree crop had been dense in parts, but notwithstanding this there was a heavy ground cover of *Vaccinium* over quite extensive patches to the south and west, and of bracken and grass over much of the remainder. Along the western half of the experiment there was a shallow layer of brown fibrous peat, while on the eastern half the peaty raw humus was deeper, darker in colour and less fibrous, this part being rather damp. The underlying formation was undifferentiated schists, but morainic material occurred to quite a depth in most parts. The whole area was divided into two major sections by the forest road, and parent trees were left for seeding in that section lying south of the road only. This southern area was divided into three strips, the following treatments being applied without replication. (*a*) slash removed, no burning and no soil preparation; (*b*) slash spread over area together with slash from first area; (*c*) soil preparation carried out in strips 2 ft. wide. Phosphate was applied to certain sections of each treatment in the form of bone meal at two cwt. per acre. Partly because of the closely grown, unthinned stand, partly no doubt on account of the sudden exposure of the mother trees, but largely because of concentrated Pine Shoot Beetle attack, consequent to heavy fellings, very little seed fell on the area during the early years. The other section, north of the road, which had been cleared of trees, was retained in the first instance to see if it would be re-seeded downwind by the parent trees in the southern section. It too was divided into strips cleared of brushwood, and strips with brushwood piled thereon, but practically no seeding at all took place.

GLEN GARRY FOREST, INVERNESS-SHIRE. (Expt. 2. 1932 (1933 Extension)). To find out if lack of seeding was the main reason for delay in obtaining a seedling crop, two sections of this treeless area were utilised in 1933 for a direct sowing experiment. Sowings were made in strips two feet in width comprising an eight-inch cultivated trench with, on the downhill side, the debris spread out over another 8 ins.; to make up the two foot sowing strip, 8 ins. of unaltered surface on the uphill side of the cultivated trench was also included. One triple strip was sown with a liberal amount of each of the following species: Scots pine, Norway spruce, Sitka spruce, lodgepole pine (*Pinus contorta*) and European larch, and, despite the uneven, and in places wet nature of the site chosen, the encouraging results clearly showed that lack of natural seeding was the main reason for the absence of Scots pine seedlings. It was found, however, that the best germination resulted where the soil had been stirred up, i.e., in the narrow cultivated portion of the strips. A large number of seedlings of every species was obtained in the first year. Several lengths of one yard contained over 500 Sitka seedlings but curiously enough the poorest counts were in Scots pine. A further trial of direct sowings was added two years later in a 1935 extension to the same experiment. This time, in addition to the species which had been sown in 1933, Douglas fir, Japanese larch, and *Tsuga heterophylla* were added. Again the seeds germinated well, the poorest species being Douglas fir. By this date a few natural seedlings were to be seen, but only thirty in the entire northern area.

Ten years after the first artificial sowings, a dense crop of pines (Scots and lodgepole) were growing strongly in the prepared strips. Spruces and larch had not done so well, but even these had made a fairly good crop. By 1950 some lodgepole pine were 23 ft. high (average 12½ ft.), Scots pine to 16½ ft., average 9 ft. and European larch to 22½ ft., average about 10 ft.; most Norway spruce and Sitka spruce had gone into check with average heights of 4 ft. and 2 ft. respectively. The areas sown in 1935 had also come away well. On the drier section lodgepole pine were up to 19 ft. high and Scots pine to 13 ft. Not many of the European larch had survived, but a few were up to 12 ft., only three Japanese larch remained and were not looking well, while poor growth for the spruces, Douglas fir and tsuga was recorded. In a wetter part of the section height growth was irregular, Scots pine averaging 6½ ft., lodgepole pine 9 ft. None of the other species had done well except for Norway spruce in one line where the mean height was 3 ft.

The quite satisfactory 1933 artificial sowings on the uncultivated edges of the strips in the northern half of the experiment (Expt. 2, 1932) clearly indicated that failure of natural seeding was the major reason for the almost complete absence of Scots pine regeneration. In each of the sections among the parent trees in the southern section (Expt. 1. 1932), therefore, 20 ft. squares were laid off and sown in 1935 with a mixture of the following tree species without any ground preparation whatsoever: European larch, Scots pine, Norway spruce, Sitka spruce, lodgepole pine (*Pinus contorta*), Douglas fir, Japanese larch, *Tsuga heterophylla*. But when examined in 1949 this (1935) direct sowing extension revealed only two rather miserable spruce seedlings. Occasional natural Scots pine seedlings were found but only once or twice were patches seen with sufficient Scots pine seedlings over 1 ft. tall and likely to make a crop. The condition of the mother trees is now good. Crowns have improved very much from the thin sparse condition which followed the fellings of 1929/30 and the trees may yet produce heavy falls of seed. Much the most interesting development however, is the fine and in places dense natural growth of rowan and birch, which seems likely to clean the ground of the matted growth of heather, bilberry and grass and to form the natural precursor to a new pine crop.

GUISACHAN FOREST, INVERNESS-SHIRE. During 1936 a small experiment was laid down to investigate the possibilities of aided or unaided regeneration from old natural Scots pine trees in this grand natural forest. The treatments included burning and screefing in strips of the strong heather vegetation and the laying out of some inverted turfs. A good seed fall must have ensued, as the burned and screefed portions soon showed fairly satisfactory seedling crops. In June 1937 excellent germination and survival on the screefed strips and turfs was reported, it being noted that this was probably due to the prolonged snow covering in the preceding winter and spring; burnt areas also showed a fair number of seedlings, but on all unprepared ground seedlings were very scarce. Five years later (December, 1942) burned areas showed a fairly good crop of Scots pine seedlings averaging from 6 to 9 per square yard and from 12 ins. to 18 ins. high. Part of this area had previously been enclosed by a wire netting cage, to discover how much damage had previously been caused by blackgame and capercaillie. There was, however, very little if any difference in the number of seedlings in the caged and open sections. By this time the screefed strips showed not quite such good results as the burnt patches, and on the wetter area where turfs had been laid out the seedlings previously reported had all died off.

GUISACHAN FOREST. (Expt. 1. 1943.) The Chairman of the Forestry Commission, Lord Robinson, inspected the experiment in 1942, and instructed the Research Branch to take over an adjacent area. He wished the drier parts planted with Douglas fir, and the wetter parts drained and planted with Sitka spruce, leaving any natural Scots pine seedlings that happened to come in. When inspected in February, 1949, it was found that the growth of the turf-planted Sitka spruce on the flushes had been good, but the Douglas fir on the heathery knolls was making a very slow start. Apart from the original seedlings there had been practically no further natural regeneration on any of the ground types.

GLEN LOY FOREST, INVERNESS-SHIRE. The staff of the then North of Scotland Division had been interested in natural regeneration in this native forest also. A typical area specially enclosed for study in 1934 contained groups of old native Scots pine and showed some regeneration of the pine, but only on the drier heathery knolls. In the better semi-flush depressions, with fresh soil or peat, rowan and birch are coming in strongly. When visiting recently with Dr. M. L. Anderson and the District Officer we felt sure that successful Scots pine regeneration was much more likely to follow this birch/rowan stage than to come directly on any other ground type. It would be desperately slow in competition with heather on the knolls; the deeper peat bogs were a most unlikely seedbed and, unaided, too poor altogether. Some Scots pine artificial sowings had been made in 1935 upon material excavated from the drains, but, as so often happens, the seedlings had soon disappeared.

RANNOCH FOREST, PERTHSHIRE. (Expt. 1. 1949.) The most recent work designed to investigate natural regeneration and methods of assisting it, was carried out in 1949 in the Black Wood of Rannoch, a famous natural Scots pine wood, in north Perthshire. As in the other "remnants" there were areas of pine with considerable blanks between. Exploitation during the recent war had removed most of the best native trees, and for many years grazing by deer and feeding by capercaillie had stopped general regeneration, although one or two patches were found.

In addition to actual experiments, observations have been made on square yard quadrats in two areas where natural regeneration was plentiful (*a*) on *Calluna* knolls and (*b*) on spoil from drains in a *Juncus* flush. Weeding, and top dressing with phosphates were applied in certain quadrats.

By 1950, Scots pine seedlings on the *Calluna* knolls were in most cases in an unhealthy condition owing to weevil damage. On the drainside spoil all plants had vanished due to frost lift or weevil damage. Phosphate and weeding have had little effect, in fact weeding of the heather was if anything, harmful.

The two experimental areas (one on *Calluna*, the second on *Molinia*) had been given preparatory treatments as under:—

(*a*) Control
(*b*) Vegetation burnt
(*c*) Vegetation killed by sodium chlorate
(*d*) Vegetation pulled by hand.

In all cases hand dug furrows were then added at ten feet spacing and to certain parts phosphate was applied. The main intention was to observe natural regeneration in the area, but, to guard against its complete non-appearance, direct artificial seeding was done on the heather area: (i) on the ridges, (ii) on the furrows and (iii) on the ground direct. In the rich vegetation on the *Molinia* area artificial seeding was practical only on the furrow ridge.

On the heather site, by the autumn of 1949, the percentage of stocked patches was 25% on the ridges and 38% in the furrows in manured areas; in the unmanured it was rather less. Away from the ploughed strips, a few sown patches were successful where the heather had been hand pulled, elsewhere there was nothing. Natural seedlings were found in a few places in the furrows, but nowhere else. Birch and rowan seedlings were, however, coming in in fair numbers. On the *Molinia* area stocking was 80 to 90% throughout. Failed patches on both types were resown in 1950, and germination was almost complete by the autumn. In the *Molinia* area two-year seedlings were doing well at that time.

By May, 1951, however, the picture was very different; in the *Calluna* area, after the bad winter and continued weevil attack, few seedlings remained, but the area was practically fully stocked with birch and rowan. On the *Molinia* area, frost and suppression has resulted in almost complete failure, even the strong two-year seedlings having vanished.

Discussion

To summarise the twenty years of experiment and investigation briefly—the results have been extremely disappointing. At best, unaided natural regeneration is erratic, undependable and a long drawn-out process. Heather killing alone is insufficient to give much advantage, and although costly soil working is an improvement, the growth which follows has even there been extremely slow compared with plantation standards. Apart from this, the risk of insufficient seed falling at the right time is a very grave one.

Luxuriant growth of mosses, which often produced great tussocks, is very common in the native forest remnants of the North and West, together with a rank growth of heather; although seedlings may germinate on the deep moss it is difficult for them to survive. Without doubt this luxuriant tangle of moss tussock and heather would be better burnt, under control, to increase the chances of regeneration, but this is frequently a difficult and often a dangerous process. The terrain is usually irregular, with morainic knolls and ridges separated by flats or wet hollows. Large boulders and old windthrown roots are common under the moss layer, and help to give an extraordinary, hummocky appearance to the ground. Treeless knolls are usually heather-clad and relatively dry; the intervening flats and hollows are often extremely wet and carry vegetation ranging from *Scirpus* or *Eriophorum* on deep bogs, to a rank growth of grasses and rushes where the soil and moisture conditions are better.

Why these native pine woods, which have regenerated themselves time and time again, should now find it so difficult to repeat the process, is really not so difficult to define. Each of the areas considered has been exploited for timber, some of them more than once during the last century. Such fellings in themselves need not have been harmful, for the light admitted and surface cultivation caused during extraction might well have improved the seedbed, except perhaps in the hollows where the natural drainage channels were likely to be blocked or upset. Much more serious however, have been the effects of the relatively recent introduction of sheep (or rather of sheep ranching) and the century or so of rigorous game preservation. Quite suddenly these innovations in land use put many natural processes out of gear. As Dr. Fraser Darling shows so clearly, ruthless destruction of all enemies of the sheep, stag and grouse very soon resulted in increasing numbers of voles, rabbits and hares, so that even if the sheep and deer themselves did not destroy all seedlings, the damage was completed by the ground game. Blackgame and later capercaillie were permitted to increase enormously, causing much direct destruction among pine seedlings and possibly also a considerable reduction in the amount of seed from the older trees.

Heather burning, practised partly to remove rank heather which impeded the short-legged sheep and tore their wool, and partly in an effort to induce young heather shoots upon which both sheep and grouse feed, destroyed natural regeneration not only of the pine but of other things helpful to pine regeneration, such as juniper, rowan, birch and even oak. Yet although fire obviously must destroy any existing regeneration, and repeated burnings may indeed make conditions for regeneration worse than ever, it may be beneficial or even necessary once in a while to burn certain very rank conditions of heather and moss in order to give tree seeds a chance to germinate and survive.

Even more disastrous than their direct effects, grazing and repeated burning increased the development of peat by causing the raw humus layers to solidify into a tough, felted condition, thus increasing the swampiness of the ground surface and encouraging sphagnum mosses to flourish. In turn the natural drainage channels became blocked, and led to the development of peat much more rapidly than might be expected. It is quite clear that the peat-forming process is less likely to develop under a tree crop, even though it is merely a thin screen of birch or rowan; but where no tree crop has been allowed to survive in these natural pine wood areas, we are witnessing a process of soil degeneration which steadily gains momentum.

Experiments at Rannoch and elsewhere have shown how futile it is to expect natural regeneration on the richer flushes, even if one throws out inverted turfs from ditches—the vegetation is much too strong. On the other hand, it was frequently shown that on the heather knolls and drier heathery regions a little stirring up of the surface layers increased the chances of natural regeneration, though the subsequent growth was extremely slow. The experiments prove how much depends upon a heavy fall of seed; but the records show how infrequently this happens in the old native pine woods concerned.

The sentimental reasons for leaving the regeneration of these northern, native pine woods as much to nature as possible are substantial; but unhappily the investigations prove that nature, having been obstructed so ruthlessly during the past century, may be unable to effect the repair unaided where the ground has deteriorated too far. Where the deterioration is less advanced, most of a century may well be required for natural regeneration to reinstitute itself—even with adequate fencing. For these reasons, therefore, a certain amount of assistance will clearly be necessary on some types of ground, and very helpful on others. To supplement the surface stirring produced by the extraction of logs for instance, a form of cultivation such as heavy disc ploughing would improve both the drainage and the seedbed conditions for any seed which might fall. Such work would be done only when a heavy seed-fall was imminent. After the seed had germinated it would be of further assistance if selected seedlings were given a manurial dressing. But quite apart from these improveable factors, success depends a great deal on weather. A suitable germinating season, and absence of drought in the first summer, only form a fraction of the necessary conditions. Winter snowfall is probably important to protect the seed from birds, and to keep the ground suitably moist, while of fundamental importance is a sunny season to provide sufficient vigour to the mother trees and so induce them to cone. The fact that the chance of these favourable conditions all arising in the proper sequence is remote, explains perhaps better than anything else the very limited chances of a successful regeneration in these Caledonian pine woods. It may well be true that a delay of thirty to fifty years in obtaining an established crop of natural seedlings is in this case justifiable, even admitting the unsatisfactory branchiness and irregular nature of all but the most complete and uniform seeding crop. On the other hand there is not the slightest doubt that by well-tried methods a plantation could be established satisfactorily in these areas in four or five years, even if the species were restricted to artificially raised seedlings from seed collected on the area. It is equally certain, although admittedly beside the point, that much more valuable crops of timber could be grown on this land if other species such as Japanese or hybrid larch, Sitka spruce, *Tsuga heterophylla* and even Douglas fir were to be employed.

As a practical compromise it is suggested that:

I. While the old crop is dense, several thinnings will be necessary to build up adequate crowns for seed production.

II. Seeding fellings should be delayed until a very heavy seeding is about to fall.

III. The heather should be burnt, if at all possible, before the seed fall.

IV. Full use should be made of such tools as the draining and disc ploughs, to provide much needed additional drains and better seedbed conditions.

V. If seeding is successful, phosphate and possibly nitrogen should be applied to selected seedlings.

VI. Where seeding is unsuccessful by the end of the second year, the expensive cultivation, etc., should not be wasted; planting must be carried out.

VII. Areas which support a promising crop of birch or rowan should be left to nature, with good hopes of ultimately successful pine regeneration.

POSITION OF PLANTING ON PLOUGHED HEATHLAND

By J. W. L. ZEHETMAYR

Assistant Silviculturist

Ploughing of heathland prior to planting has been common practice for almost twenty years now, and whenever non-continuous—as opposed to complete—ploughing has been employed the problem has arisen as to where one should plant. A single ridge and furrow with its adjoining strip of untouched moor gives a variety of micro-sites, and as the depth to which ploughing has been carried has increased, so the range of choice has widened. The modern deep-going plough will cut a furrow twelve or more inches deep, and turn out a ridge to match, exposing the peat and leached layers, and often the pan and subsoil as well. Water relations will vary greatly at the extremes of micro-elevation, some two feet in all, as also will exposure; in addition there may be actual shading of the plants in the early years. These factors are bound to have an effect on newly inserted plants, particularly on the smaller one-plus-one transplants and the first year seedlings which are being increasingly planted today. It is thus worth putting on record, even in an incomplete state, the results of a series of trials both on the nutrient value of the various layers of a podsol, and also the effect of planting in various positions on deep single-furrow ploughing.

While the results are considered entirely from the standpoint of early losses and growth, it is possible that the shape and balance of the root system, and hence the long term stability of the crop, may be determined partly by the position of planting.

The first experiments which bear on this subject are of a more fundamental type than the current series, and were laid down at the instigation of Dr. (now Sir William) Ogg, then of the Macaulay Institute for Soil Research, Aberdeen. Two experiments, at Teindland, Morayshire and Inchnacardoch, Inverness-shire, investigated the effects of planting into each layer of the profile. To do this, small plots were stripped of the various horizons and the plants carefully set into the layer below. Results are summarised in Table 8 below:—

HEIGHT GROWTH OF CONIFERS PLANTED IN DIFFERENT SOIL PROFILE LAYERS

Table 8

Profile layer in which planted	Teindland Expt. 50. 1934*					Inchnacardoch Expt. 106. 1934					
	Depth in inches	Heights at 8 years in feet				Depth in inches	Heights at 12 years in feet				
		Scots pine	Lodge-pole pine	Japan-ese Larch	Mean		Scots pine	Lodge-pole pine	Japan-ese Larch	Mean	Sitka Spruce
Surface peat	0-4	2.4	3.6	4.8	3.6	0-3	11.2	12.8	10.0	11.4	1.1
Leached layer	4-10	2.7	3.8	5.4	3.7	3-7	11.1	13.4	12.7	12.5	1.1
Pan and deposition.	10-12	2.4	2.8	5.8	4.0	7-9	10.8	12.7	9.1	10.9	1.6
Subsoil	Below 12	2.9	2.8	4.7	3.5	Below 18	9.0	13.2	10.1	10.8	2.3
Difference necessary for significance at 5%	—	0.6	1.2	1.7	—	—	1.5	2.7	1.1	—	—

* Expt. burnt in 1942. Sitka spruce completely destroyed, being in check at the time.

Though results are rather erratic, and there were insufficient replications to give significant effects in all cases, it may be seen that the pines and larch have grown best where planted into the leached layer. Sitka spruce has grown best on the subsoil, and this may be explained by the fact that the other treatments have been invaded by heather, thus causing checking of the spruce; but this has not occurred on the exposed subsoil. It is to be regretted that comparison was not made with an inverted turf or mound, corresponding with the normal practice of the day, since while it is well known that this is better than direct notching into the peat, the comparison with the other layers would be valuable.

During the early years of ploughing there was considerable divergence of opinion as to the correct position for planting, which may be exemplified from the Wykeham research area in Allerston Forest, Yorks. With shallow-going ploughs, the ridge top, ridge side, furrow, and even the unbroken strip of ground have all been used as the planting position throughout one or more experiments, with only one attempt, in 1934, at critical comparison. This trial used Scots pine and showed no appreciable differences, almost certainly due to the unfortunate fact that the ploughing on which it was planted was four years old; at that time the importance of using fresh ploughing was not appreciated.

In 1943, with the development of the R.L.R. deep-going plough, the problem was intensified. While awaiting information it was necessary to plant somewhere, and a method known as "step planting" was developed, in which the plant was inserted in a prepared position cut with a spade on the side of the ridge.

In 1945 an experiment was laid out in the Broxa experimental reserve at Langdale Forest, Yorks., to investigate this point. Treatments are illustrated in Fig. 1, and results are shown in Table 9, and clearly demonstrate the advantage of planting in the furrow. While the step gives results almost as satisfactory, by this method the actual planting is twice as expensive owing to the time spent in cutting the step.

HEIGHT GROWTH AFTER VARIOUS PERIODS, FIRST YEAR LOSSES, AND RATE OF PLANTING FOR SCOTS PINE AND SITKA SPRUCE PLANTED AT DIFFERENT POSITIONS ON DEEP PLOUGH FURROWS

Table 9 Broxa. Expt. 17. 1945

Position of planting	Scots pine (without slag)				Sitka spruce (planted with slag)				No. planted per man-hour
	1st yr. losses	Height in feet after			1st yr. losses	Height in feet after			
		2 yrs.	4 yrs.	6 yrs.		2 yrs.	4 yrs.	6 yrs.	
Control on the unbroken strip	8%	0.8	2.15	3.4	Nil	1.45	2.3	3.0	121
Top of ridge	16%	0.75	1.65	3.2	,,	1.35	1.9	2.6	144
Step in ridge	3%	0.95	2.4	4.2	,,	1.65	2.45	3.4	92
Bottom of furrow	3%	1.05	2.75	4.4	,,	1.8	3.1	3.8	168
Difference for significance : 5%	—	—	0.27	0.24	—	—	0.25	0.33	—
1%	—	—	0.41	0.37	—	—	0.38	0.50	—

Losses were negligible in the step and furrow while the improvement in growth in these positions is highly significant for both species. The growth on the unbroken strip is surprisingly good, but it must be remembered that the latter is very narrow with this form of ploughing and that checking of the spruce, as the heather re-invades the ploughed area, is likely to set in first in this position.

This experiment was followed by a series planted in 1948-50, preliminary results of which are presented in Tables 10 and 11. Here the species used was Sitka spruce throughout, and several age-classes were used, viz.:

First year seedlings from heathland nurseries P.48-50

One-plus-one transplants from heathland nurseries P.48 only.

Two-plus-one transplants from established nurseries P.48-49.

Together with five of the positions of planting illustrated in Fig. 1, two depths were used, one third of the shoot being buried in the "deep" planting.

Losses of transplants in all these trials were negligible.

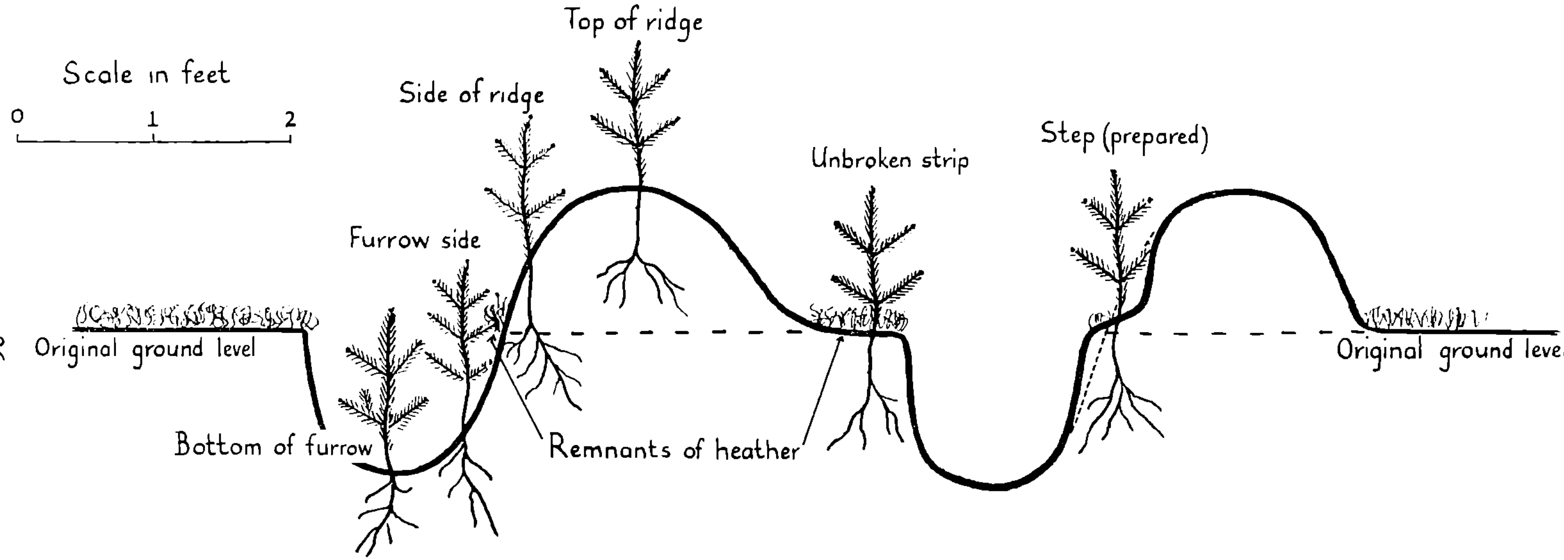

Fig 1. Diagram showing six possible planting positions on ploughed heathland

Losses of first year seedlings are shown in Table 10:—

Table 10 PERCENTAGE LOSSES OF SITKA SPRUCE, PLANTED AT VARIOUS POSITIONS ON PLOUGHED GROUND, AT THREE SEPARATE FORESTS %

		Teindland		Broxa			Kilcoy	Mean	
		75.P.48	78.P.49	32.P.48	54.P.49	75.P.50	2.P.49		
Top of ridge	N	58	11	13	23	2	28	22	23
	D	43	27	17	25	2	30	24	
Ridge side	N	35	30	30	32	2	30	26	25½
	D	48	25	28	22	5	22	25	
Step in ridge	N	63	32	10	13	0	32	25	23½
	D	53	22	27	12	0	15	22	
Furrow side	N	31	13	10	10	0	5	12	11
	D	30	2	15	23	0	0	12	
Bottom of furrow	N	11	7	22	13	0	0	9	13
	D	35	15	22	20	2	7	17	
Means		40 42 41	19 18 18½	17 22 19½	18 20 19	1 2 1½	19 15 17	19 20 19½	

Notes: N=Normal depth. D=deep planting. "75.P.48" signifies "Expt. 75, 1948".
All trees were planted as first year seedlings.
Assessments of lots marked "P.48" were made two seasons after planting.
Assessments of lots marked "P.49" and "P.50" were made one season after planting.

From this extensive series of trials it is quite apparent that furrow planting, on average, halves the losses in the early years. It is probable that this is almost entirely due to the damper conditions in the furrow. Of the sites concerned, the soil at Teindland is derived from boulder clay, at Broxa from very stony loam, and at Kilcoy from sandstone.

In the oldest (1948) experiments of this series the first height measurement taken at 3 years of age has given results set out in Table 11:

Table 11 HEIGHT GROWTH, THREE YEARS AFTER PLANTING, OF SITKA SPRUCE PLANTED AT VARIOUS AGES AT VARIOUS POSITIONS ON PLOUGHED GROUND AT TWO SEPARATE FORESTS

	Teindland, Expt.75. 1948				Broxa, Expt.32. 1948			
	1+0	1+1	2+1	Mean	1+0	1+1	2+1	Mean
Top	0.7	1.35	1.15	1.07	0.9	1.85	1.25	1.33
Ridge side	0.75	1.45	1.35	1.18	1.3	2.1	1.5	1.63
Step	0.7	1.3	1.35	1.12	1.8	3.0	2.1	2.30
Furrow side....	0.95	1.9	1.35	1.40	2.0	3.2	2.4	2.53
Bottom	1.0	1.9	1.35	1.42	2.1	3.35	2.65	2.70
Mean....	0.82	1.58	1.31	—	1.62	2.70	1.98	—
Critical Difference for position of planting, for probability of:			5% 1%	0.29 —				0.36 0.51

All heights are in feet

1+0=First year seedlings. 1+1=One-plus-one transplants.
2+1=Two-plus-one transplants. All ages at time of planting.

Notes: Comparison of height growth as between depth of planting only, ignoring other factors, gave the following results:

Teindland: Normal 1.25 ft. Broxa: 2.11 ft.
Deep 1.24 ft. 2.09 ft.

These results confirm those given for Experiment 17 at Broxa in Table 9 above, though at Teindland the result is so far significant only for the fastest growing lot, the one-plus-one transplants. Throughout the series, depth of planting has had remarkably little effect on either losses or growth.

As a result of these experiments, the planting position has been changed, in recent experiments at Broxa, to the furrow side for the following reasons:

(i) That the furrow is the best position for growth and survival has been demonstrated.

(ii) The furrow side position, being between ridge and furrow, puts the plant as far as is possible from competing vegetation.

(iii) The side rather than the bottom avoids the risk of damage from water running or lying in the bottoms after heavy rain.

(iv) A better chance is provided for the roots to develop outwards in all directions, rather than only along the ridges as may occur with ridge planting.

It is appreciated that this result does not apply to areas where the furrow is required as a drain, but it does appear that there is scope for trial of this position wherever ploughing is used to cultivate ground and remove competition, rather than for drainage.

PROVENANCE STUDIES

By M. V. EDWARDS

Assistant Silviculturist

New European larch Provenance Trials

The first part of the trial of European larch of various provenances, with Japanese and hybrid larch, in places where previous European larch crops have suffered from "die-back", was commenced with plantings at Drumtochty forest, Kincardineshire, and Thornthwaite forest, Cumberland in 1951. The same sets of plants were also supplied to Coed y Brenin forest, Merioneth. The progress of these experiments should help to elucidate the importance of provenance in the resistance of larches to the "die-back" condition which has caused alarm in so many places.

Some Differences between European larches of Selected Provenance

Measurements of some of the commonly-observed characteristics of different provenances of European larch were made at Drummond Hill forest, Perthshire, in two experiments started in 1935. It is often remarked that the branch form or size varies in different provenances, and certainly in the experimental plots it appears that the true Sudeten larch has finer branches but more of them. It also has a characteristic pendulous form of the twigs, specially noticeable in youth, the needles being less tightly clustered, lighter green in colour, with the pale almost silvery colour of the twig being evident through them. These latter characteristics did not prove easy to measure, even with the use of colour charts, and they are not very definite except in provenance collections, where the plots of different larches adjoin and can be seen simultaneously. Many of them are associated also with Polish and Carpathian as well as Sudeten larch, and are probably more typical of east European as compared with the west European larch from the Alps.

The Sudeten, Scottish and Alpine provenances also differ significantly in their resistance to canker.

CHARACTERISTICS OF EUROPEAN LARCH OF VARIOUS PROVENANCES

Table 12

Provenance	Mean Height feet (*a*)	Mean breast-height Girth ins. (*b*)	Girth/Height ratio (*b*/*a*)	No. of branches per tree between 4 ft. and 6 ft. from ground	Girth ratio:— Largest branch/Tree at breast height	Mean No. of cankers per tree up to ten ft. height
Drummond Hill Forest, Experiment No. 8. 1935, Extension 1937. Age 19½ yrs.						
German Zulzhoff, Germany*	29.8	12.4	0.42	25.8	0.136	0.9
Scottish Tom-an-Uird, Morayshire	24.8	11.6	0.47	20.6	0.168	2.8
Advie, Morayshire	22.8	10.6	0.46	20.8	0.196	3.3
Glencoe, Argyll	24.5	11.7	0.48	19.5	0.186	3.9
Glentress, Peeblesshire	20.2	9.6	0.48	21.5	0.213	2.3
Tullimet, Atholl, Perthshire-	21.5	10.9	0.51	21.8	0.190	3.1
Loch Kennard, Perthshire	19.5	10.4	0.53	21.5	0.242	2.1
Alpine Central Alps, 2,300-3,300 ft.	22.7	12.2	0.54	25.5	0.190	4.7
N. Tyrol, 1,900-2,600 ft.	21.5	11.3	0.53	23.3	0.186	2.9
French Alps, 2,800 ft.	14.4	8.3	0.58	22.4	0.302	8.1
Standard error of the mean....	± 0.92	± 0.60	—	±0.96	±0.010	±.063
Difference necessary for significance 5%	2.6	1.7	—	2.5	0.029	1.8
Difference necessary for significance 1%	3.5	2.3	—	3.3	0.038	2.4
Drummond Hill Forest, Experiment No. 7. 1935. Age 14½ years						
Munster, Switzerland, over 3,800 ft.....	—	10.0	—	23.2	0.179	large (not counted)
Silesian (Sudeten?)	—	11.6	—	26.3	0.159	medium (not counted)
Darnaway, Morayshire....	—	10.7	—	21.5	0.146	medium (not counted)

* Guaranteed Sudeten provenance.

Some additional data have been obtained from another experiment at Kirroughtree forest, Kirkcudbrightshire. Here there is only one plot of each provenance, and there are insufficient trees to obtain a reliable figure. However it is interesting to find that here, in a milder climate, the growth of larch is faster, the number of cankers much less, but still greatest on the French Alpine provenance and that the data for branch form are similar.

These figures illustrate the fine-branched habit, with more numerous branches, of the true Sudeten larch, and a similar tendency in Silesian larch of reputed Sudeten origin; and the relatively poorer growth, coarser branching and lesser resistance to canker of the Alpine provenances. It also substantiates the visual impression that the Sudeten is a more slender tree. Trees of Scottish provenances, which are of unknown and possible mixed ultimate origins, are intermediate in character.

These characteristics are however biometrical, and true only on the average of a large number of individuals, because the variation is continuous. As has been shown by Rubner and Svoboda's work, (*Intersylva*, 1944) on the cones, it is not possible to measure one or two trees or cones and from that deduce their parentage.

The International Larch Provenance Experiment, 1947

One set of plants of this experiment is situated at Drummond Hill, Perthshire. Here the site is old pasture land, exposed, and at an elevation of 840 to 995 feet.

The plants were, with one exception, from the same nursery as the plants used in the five English forests where this experiment is situated, but the planting was done one year later in Scotland. It is too soon to give any conclusions as to the success of the various provenances. The largest plants at the end of the nursery stage are not now always growing the fastest. But it is clear, as in England, that the best lots include Aldroughty, Morayshire; Proskau, Upper Silesia; and Japanese larch; but the Sudeten larch (Parchowitz, Moravia) is not so outstanding in Scotland as in England in this experiment. Among the poorest lots at most forests is Lotschenthal, Wallis, the high-level Swiss Alpine provenance.

It is of interest to note that trees of the Aldroughty provenance were so large when planted that it was feared that they might suffer damage, and a second Scottish lot from Lethen was introduced as a safeguard, from a different nursery. The Aldroughty provenance is still the best, whereas the small Lethen plants have not established themselves well, and are still the smallest.

Hybrid Larch

The following studies of hybrid larch plantings (*Larix europea x L. leptolepis*), though not, strictly speaking, provenance matters, are included here for convenience, as the methods of assessment were similar to those used for the European larch provenance studies reported above. A comparison between first, second and third generation hybrid larch plantings gave the following results. (See Table 13.)

The figures suggest that the hybrid larch is a finely branched tree. The second generation of hybrids is less so, and the third generation is more coarsely branched. The third generation plots are also the most irregular in growth, which on the average is inferior, but it must be remembered that after one or two thinnings the selection thus taking place may result in a good crop from the best trees that remain. The third generation crop is the only one of the hybrids that has suffered any material degree of canker.

Confirmatory data on the height and girth of the trees are available from Cardrona Forest Experiment No. 1. 1937, (Peebles-shire), where however the other characteristics were not measured.

GROWTH RECORDS OF HYBRID LARCH OF THREE SUCCESSIVE GENERATIONS

Table 13

Provenance	Mean Height feet	Mean breast-height Girth ins.	No. of branches per tree between 4 ft. and 6 ft. from ground	Ratio of girth of largest branch (between 4 ft. and 6 ft.) to tree at breast height	Mean no. of cankers per tree up to 10 ft. height
Drummond Hill Forest, Experiment No. 9. 1936 (Height at age 14½ years, other data at age 13½ years)					
Probably first generation:—					
Glamis	32.5	14.5	20.8	0.12	Nil
Second generation:—					
Dalmarnock (Dunkeld)	32.1	12.9	19.1	0.13	0.03
Whitegate (Dunkeld)	31.8	12.7	18.0	0.13	0.16
Killiechangie (Dunkeld)	33.4	13.9	19.5	0.13	0.14
Newtyle .... (Dunkeld)	31.4	14.2	20.1	0.14	0.07
Lower Warren (Dunkeld)	32.2	13.7	19.0	0.14	0.12
Third generation:—					
Ladywell, Dunkeld	27.8	11.5	17.7	0.17	1.56
Standard error of the mean	± 0.88	± 0.51	±0.77	±0.008	—
Difference necessary for significance at: 5%	2.6	1.5	2.2	0.02	—
Difference necessary for significance at: 1%	3.5	(2.0)	(3.0)	(0.03)	—
Cardrona Forest. Experiment No. 1. 1937					
Probably first generation:—					
Glamis Grade I plants	25.2	14.6	—	—	—
Glamis Grade II plants	21.7	11.8			
Mean	23.4	13.2			
Second generation:—					
Dalmarnock (Dunkeld)	22.9	12.5	—	—	—
Whitegate (Dunkeld)	22.8	12.5			
Killiechangie (Dunkeld)	22.3	12.1			
Newtyle (Dunkeld)	22.2	12.5			
Lower Warren (Dunkeld)	22.8	12.8			
Third generation:—					
Ladywell, Dunkeld	21.6	12.0	—	—	—

Nursery Study of the Progeny of Free-pollinated Japanese Larch at Dunkeld

The progeny of a collection of larch seed from the original Japanese larch trees on the Avenue at Dunkeld, which have been the main source of supply of the hybrid larch, *Larix eurolepis*, was studied at Wykeham heathland nursery, Allerston Forest, Yorks. These trees are probably partly self-pollinated among themselves, and partly cross-pollinated from European larch trees on Kennel Bank, just behind the Avenue. The plants, both first year seedlings and one-plus-one transplants, were classified by stem and root colour by the methods described by Dr. E. V. Laing in the *Scottish Forestry Journal*, Vol. 58, 1944. The main diagnostic feature of the stem was the colour. The classification by root colour gave very similar results, but was found to require washing of the root below the collar, and was thus more laborious.

Though the seed for the Japanese trees was obtained under free pollination, there was no sign of a large proportion of purely Japanese plants in the progeny. Instead, the variation appeared to be perfectly continuous, with a preponderance of hybrids resembling the Japanese parent more than the European. There was difficulty in distinguishing between the grades, and in fact five classes were used:—Japanese, European and hybrid types, with intermediates between them. But it will be seen from the figures below that the largest plants, displaying the greatest heterotic vigour, were the most characteristically hybrid in appearance.

GROWTH RECORDS OF VARIOUS CLASSES OF HYBRID LARCH

Table 14

Hybrid classification as one-plus-one transplants	Size classes when lined out as first year seedlings						Total	Mean Height inches
	2″	3″	4″	5″	6″	7″		
Japanese	23	23	9	—	1	—	56	2.8
Japanese/Hybrid intermediate	250	97	42	10	7	5	411	2.6
Hybrid	152	161	81	55	27	4	480	3.3
European/Hybrid intermediate	10	3	1	—	—	—	14	2.3
European	—	—	—	—	—	—	0	—

This suggests that in general practice the selection of hybrids also includes a grading by vigour, and thus past comparison between the hybrid and European or Japanese larches have tended to be comparisons between the most vigorous part of the hybrid progeny with the mean population of the European or Japanese species. Without controlled pollination, this cannot be avoided. Plants from this experiment have been planted at Broxa, Langdale Forest, for later investigation when they produce cones.

Scots Pine

A collection of plants raised almost entirely from seed of old trees forming the relics of the natural Caledonian pine forest, was planted in 1949 in Glentrool Forest, Kirkcudbrightshire. The site chosen was in a west coast type of climate which has proved difficult for Scots pine, which often tends to suffer from wind-blast and browning of the needles. It is hoped that some of the old natural Scottish seed lots may prove resistant.

The most noticeable result at the end of the first season is the damage which has occurred to large plants, those lots which had grown larger in the nursery suffering the most. Some plots of younger pine grown from seed from Canada did not suffer. It will take some time for differences due to seed provenance to become evident.

An assessment of one of the early provenance trials at Inchnacardoch forest (Experiment No. 58. 1928) was made in a manner similar to the larch experiment. The well known Riga provenance is the most vigorous of the four foreign lots in the experiment, but has at the same time the greatest number of branches. On account of the great number of branches, their size compared to the stem is shown to be smaller. This does not agree entirely with the appearance of the trees, as many of them tend to have one very large branch higher up, and their general stem form is poor.

CHARACTERISTICS OF VARIOUS PROVENANCES OF SCOTS PINE

Table 15

Provenance	Mean Height feet	Mean Girth ins.	No. of branches per whorl, nearest to six feet from ground	Girth ratio: largest branch/tree at breast height	Percentage of stem class I trees	Volume of first thinning 1950 cubic feet per acre*	Latitude and Longitude of origin
var. *lapponica* Kittila, N. Finland.		complete failure					Lat.67½°N Lon.25°E
Viborg, Finland	24.5	11.5	5.9	0.18	52	116	Lat.61°N Lon.29°E
var. *rigensis* Riga	28.9	13.7	8.3	0.17	12	518	Lat.57°N Lon.24°E
var. *haguenensis* Alsace, France.	26.7	12.1	6.7	0.18	41	344	Lat.48¾°N Lon.7¾°E

* Based on plots of .072 acres each.

Sitka Spruce

A collection of Sitka spruce lots from Washington, United States of America, was planted out in Glendaruel forest, Argyll, for comparison with plants from Queen Charlotte Islands (British Columbia) seed. In addition, two special lots from Washington and British Columbia which had proved more or less frost-tender respectively in the nursery, were included.

The same Washington provenances were also planted at Kielder Forest (Tarset block) in Northumberland, in comparison with the same Queen Charlotte Island provenance and home-collected seed from a good stand in Harwood forest, Northumberland, which had also been raised originally from Queen Charlotte Island seed.

WORK ON AFFORESTATION PROBLEMS IN SCOTLAND AND NORTHERN ENGLAND, 1950-51

By J. W. L. ZEHETMAYR
Assistant Silviculturist

Trial Plantations on Difficult Sites

A larger programme of experimental planting has been undertaken in the year under review than ever before. In the north, in the spring of 1951, over one hundred acres were planted, using 230,000 plants and thirty-eight species. This was due mainly to the success of the trial plantations on poor peat planted immediately after the war, and hence the desire to test out these methods on a wide variety of sites. In brief, the system, which has already been described (J. A. B. Macdonald, Plantations on Peatland, *Report on Forest Research*, 1950) is one using the Cuthbertson draining plough and phosphatic manuring, with scattered trees of a number of species within a matrix of the expected safest species. Since the transport of a plough to remote sites is expensive, these plantations have been made large enough to give long term results, five acres being the minimum normally attempted. Details are shown in Table 16.

TRIAL PLANTATIONS LAID DOWN IN 1950-51

Table 16 S.S. =Sitka Spruce. P.C. =Lodgepole pine

Site	Approximate Area (acres)	Main features	Main species
Skiall, Caithness	8	Very exposed, mineral soil or peat	SS
Forss, Caithness	6	Very exposed, mineral soil or peat	PC & SS
Watten, Caithness	20	Exposed, deep poor peat	PC
Strathy, Sutherland	6	Deep poor peat....	PC
Drumtochty, Kincardineshire	5	Exposed and high lying area....	PC
Kielder, Northumberland	11	Exposed and high lying peat area	PC
Halifax Corporation Water Catchment area, Yorks.	14	5 areas ranging from poor peat to mineral soil, all subject to industrial fumes.	SS & PC

The planting in Caithness has been undertaken on behalf of the Department of Agriculture for Scotland, and that on the Halifax catchment area on behalf of the Corporation. In both cases the results will be of great value in providing data on growth on poor sites. The plantations at Drumtochty and Kielder were planned at the request of the Conservator of Forests, whose staff then carried out the work; Research Branch supplied plants and assistance and will maintain the records.

In all these trial plantations the site conditions due to exposure, soil or fumes are such that they would, for normal purposes, be regarded as unplantable; and it will, in most cases, be many years before a decision to plant on a larger scale can be taken. As the areas of similar ground available tota many thousands of acres, the practical importance of these trial plantations is obvious.

Species and Mixtures Trials

When work started on the better peat types, and on the heathlands, the research problem was to establish a forest crop on areas which had borne at the most poor pine scrub. Planting of pines and larches on the heaths, and pines and spruces on the peats, has now, however, become commonplace with improved methods of ground preparation and planting. In recent years, therefore, attention has been turned to the possibility of using alternatives to the common species with the object of breaking up large pure blocks, both for reasons of amenity and insurance against risks, giving a wider range of produce, and also in order to introduce more productive or more valuable species.

A range of trials has therefore been undertaken involving large numbers of species;

(1) The first series tests the introduction of species into ploughed lanes cut through young spruce or pine. The object in these trials is to provide the optimum environment for more tender species, i.e. overhead light and side shelter, fresh ploughing and phosphate. Some twenty-five species, including less common pines and spruces, larches, silver firs and hardwoods have been planted in the last two years in Norway spruce areas in Kielder Forest, Northumberland, and in Scots pine crops at Newtyle, Morayshire; Devilla, Fifeshire; and Allerston, Yorkshire. These plots are on a very small scale, except that on the heaths at Newtyle and Allerston the most promising species: beech, Douglas fir, *Abies grandis* and *Tsuga heterophylla* have been established on a scale to give quarter acre mixed plots with Scots pine.

(2) Much the same considerations, i.e. the greatly improved chances of establishment with current methods, have led to a number of trials

of species in pure plots or in mixture, using those species that have hitherto been tried only on a very limited scale. These plantings are being made of such a size as to give long term results, as follows:—

INCHNACARDOCH, INVERNESS-SHIRE. A number of species which have given variable or promising results in past experiments have been retried in mixture with lodgepole pine on poor peat, on a site varying from shallow knoll peat to deep basin peat. Species tried include European and hybrid larches, Douglas fir, *Picea omorika*, *Tsuga heterophylla* and *Abies grandis*.

KIELDER, NORTHUMBERLAND. An area of thirty or more acres has been taken over for a series of half-acre forest plots of all promising species, and in addition certain mixtures. A start has been made with the planting of twelve plots. Small intervening or irregular areas have been filled with 100-plant plots of species about which enough is not yet known to warrant their inclusion in the main series.

LANGDALE FOREST, YORKSHIRE. Planting in the Broxa experimental enclosure is now nearing completion. Accordingly a series of demonstration plots has been planted of the crops which are considered possible for the area, in the light of the available evidence. The main series consist of Douglas fir, Sitka spruce, *Tsuga heterophylla* and *Abies grandis*, in mixture with Japanese larch or Japanese larch and Scots pine. A number of pure controls have been provided, together with crops such as lodgepole pine, hybrid larch and mixed Scots and Corsican pines, no examples of which were available in the experimental area.

Direct Sowing

The series of sowing trials started in 1947 have been continued at Kielder and Broxa. It is interesting to note that a number of trials have been laid down by the Conservancy, on heaths in the East of Scotland along the lines which have been on the whole very successful at Broxa.

Use of First-Year Seedlings

After the variable results of early trials, semi-forest scale experiments have been initiated at Fetteresso, Kincardineshire, and Glentrool, Kirkcudbrightshire. The method is to scatter test plots of one hundred seedlings of the species being planted by the Conservancy, over the whole planting area of the current year.

It is intended to continue this scheme for at least three years, so that the economics of the use of large first-year seedlings may be worked out on the basis of the losses and growth obtained from these samples.

Manuring in Plantations

Examination of the results of certain experiments at Achnashellach Forest, Ross-shire, and Inchnacardoch, laid down in 1928, suggest that Sitka spruce may show a marked response to heavy doses of up to 30 cwts. of basic slag per acre (equivalent to 1½ lb. per plant); though for most species 2 oz. or less per plant represents the economic dose. While application of such heavy doses to all plants is not practical, it would be practical to apply such rates to a limited number per acre. Trials have accordingly been started at Inchnacardoch, and also at Watten in Caithness, in which heavy rates are applied to the spruce only, in a mixture of spruce with lodgepole pine. The difficulty of handling such mixtures normally lies in the very unequal growth rates obtained during the early years, and it is hoped that this differential manuring will provide a possible solution.

Heavy phosphatic manuring is also being tried on semi-checked spruce planted at Millbuie, Ross-shire, and Fetteresso, Kincardineshire, in 1946.

Draining

The test well investigations described last year have been extended into several of the older draining experiments, both on peat and heaths, in an attempt to correlate observed differences in growth with the level of the water table. At Newcastleton, Roxburghshire, a start has been made on a large scale test of different draining intensities and thinning regimes, as an aid to increasing wind stability in spruce crops. Half acre plots are being laid out with all combinations of light, moderate and intensive draining and of light low, heavy low and crown thinning. This is a long-term project and accordingly records of volume, increment and all windblows will be kept, probably for the entire rotation.

Brashing Experiments

A new series of brashing experiments has been commenced as a result of observations on the effect of this operation on subsequent costs in Sitka spruce which were made at the Forest of Ae, Dumfriesshire in 1948. The main result at Ae suggested that selection brashing did not reduce total costs through improved access. The new series in Scots pine and Sitka spruce test various alternative brashing systems designed to provide access to young crops.

OAK AND LARCH MIXTURES AT THE EARLY POLE STAGE

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

During the period 1927 to 1931 a number of experimental plantations of oak with an admixture of larch were established. These plantations, which are situated in the Dean (Glos.), Tintern (Monmouth), Rockingham (Northants), Micheldever (Hants.) and Alice Holt (Hants.) Forests, are mostly small-scale experiments using only a single arrangement of the mixture; however at Crumblands (Tintern Forest), the various methods used at other centres are demonstrated on a larger scale.

The plantations have now reached a stage when they are beginning to give some interesting information. Although many points are not answered by exact comparisons, the series of plantations, taken together, provides a considerable experience of this method of raising oak.

Arrangement of Mixtures

The treatments adopted at Crumblands, which are set out below, cover most of the types of mixture laid down at other sites.

1. PURE OAK planted in rows at 4 ft. x 2 ft.; 5,450 plants per acre.
2. OAK GROUPS SPACED 18 FT. APART, i.e. 134 groups per acre. Oak groups of 6 ft. square, planted with 36 oak seedlings 10 inches apart, making 4,826 plants per acre.

A single row of larch 5 ft. apart runs between each row of oak groups, and there are also two larch between each pair of groups in the row, making 750 larch plants per acre.

In all, 5,570 plants per acre.

3. OAK GROUPS SPACED 21 FT. APART, i.e. 99 groups per acre. Oak groups 6 ft. square, planted with 36 oak seedlings 10 inches apart, making 3,560 plants per acre.

   Two rows of larch at 5 ft. x 6 ft. run between each pair of rows of oak groups and there are also two larch between each pair of oak groups in the rows, making 890 larch plants per acre.

   In all, 4,420 plants per acre.

4. SIX-OAK-TO-THREE-LARCH STRIPS. The oak strips consist of 6 rows of oak planted at 4 ft. x 1½ ft., and the larch strips of 3 rows of larch planted at 6 ft. x 5 ft., making 4,360 oak and 550 larch per acre. In all, 4,910 plants per acre. Centres of oak strips 40 ft. apart. (See Plate IV facing page 67.)

5. FOUR-OAK-TO-TWO-LARCH STRIPS. The oak strips consist of 4 rows of oak planted at 4 ft. x 1½ ft., and the larch strips of 3 rows of larch planted at 5 ft. x 5 ft. making 4,300 oak and 645 larch per acre. In all, 4,945 plants per acre. Centres of oak strips 27 ft. apart.

Variations on these patterns include a reduction of the spacing of oak groups to 16 ft. at Micheldever. Groups of oak have also been sown, with varying success.

It will be seen that the number of oak planted per acre in all treatments is rather large. So far as the strip methods are concerned, our experimental evidence on the spacing of oak in pure plantation may be considered applicable, and this suggests that a wider spacing, of 4 ft. x 4 ft., is satisfactory.

We have no experimental evidence on the numbers of oak necessary per group. In these tight groups, only one tree is required to develop, indeed at about twenty years of age it is rare to find more than three equally developed dominants and there are usually less. It does not appear that groups which have had early losses are markedly inferior to fully-stocked groups, and one might hazard a guess that twelve plants are sufficient for planting such a tight group in a larch matrix.

The number of larch planted must depend to a large extent on local circumstances, the demand for small poles being an important factor. It appears desirable to keep *at least* five feet between larch and oak, otherwise the larch is likely to interfere seriously before it has reached reasonable dimensions.

While we have yet to obtain evidence on the manageability of the crop, the intermediate yields of larch, and the distribution and prospects of the oak, the original patterns do impose certain restrictions. In the groups, the choice of final crop is restricted to a relatively small number of trees. These trees are now declaring themselves, each being the survivor of a considerable number. At 21 ft. centres, there are 99 groups to the acre; at 18 ft. centres, 134; and at 16 ft. centres, 170 to the acre. The final crop will presumably consist of some 40 to 50 stems per acre, depending on the size of logs required. The reduction to this stocking from 99 trees per acre is obviously not going to allow much latitude; to maintain satisfactory distribution it appears likely to be a very formal procedure. The closer spaced groups seem to have the advantage in this respect; there is also room to accept a few good larch to grow to large dimensions at the cost of perhaps unpromising oak, without so much risk of upsetting the final oak distribution.

Regarding the strips, the six oak to three larch pattern ought in theory to reduce to an even distribution of oak at 40 ft. spacing (27 per acre). Higher stockings would not be evenly distributed, but this is perhaps of small consequence. The method will allow considerable flexibility, the choice of final crop oak is not forced at an early stage as in the groups, nor is such a high proportion of the larch in contact with oak on one side or another. The four oak to two larch strips offend in this latter respect, and do not reduce to an even distribution of oak of less than 60 to the acre.

Experience in early tending of these crops is in favour of the strips, in which weeding is a much more practicable proposition.

Relative height growth of oak and larch in mixture

At every site larch has grown faster than oak. The relationship between the heights, however, varies considerably according to site. No serious attempt can be made to examine this, owing to the variety of seed origins of both oak and larch represented, but Figure 2 gives some idea of the relative behaviour of the two species on a number of sites.

It will be seen that the greatest differences in height growth occur on the lighter soils, and this appears to be due to the larch being favoured on the latter, rather than to any very obvious response in the oak. This result would probably have been expected.

The Nursing Effect of Larch

There is a good deal of evidence to suggest improved height growth of oak in mixture with larch, as compared with that of pure oak crops. Eight comparisons have been made between various oak and larch mixtures, and the nearest contemporary pure oak crop. In each the advantage was in favour of the mixed oak, as shown in Table 17, for Crumblands.

HEIGHT GROWTH OF OAK, GROWN PURE AND MIXED WITH LARCH, AT CRUMBLANDS, TINTERN FOREST

Table 17

Age	Type of Crop	Height of Oak in feet	Remarks
20 years	Pure oak, spacing 4 ft. x 2 ft.	21 (Top height)	Mean of two plots (upper and lower)
	Oak/larch strips 6 oak/3 larch	24.7 (Top height)	Mean of three plots (upper, middle and lower).
	Oak/larch strips 4 oak/2 larch	25.5	Mean of two plots (upper and lower)
	Oak groups in larch matrix, 21 ft. centres	25.4 (Dominants in group).	
	Oak groups in larch matrix, 18 ft. centres	24.9 (Dominants in group).	

Height measurements at Crumblands, after ten seasons growth, showed no such effect, but when the crops were again measured after a further five years there were fairly appreciable differences, which appear to have increased in the last five years. The Crumblands plots are not laid out in such a way that this effect can be ascribed to treatment with certainty.

Assuming that there is such a height advantage in mixed oak, the important question is whether it will be reflected in any commensurate gain in the length of clean timber. It remains uncertain whether we can achieve this.

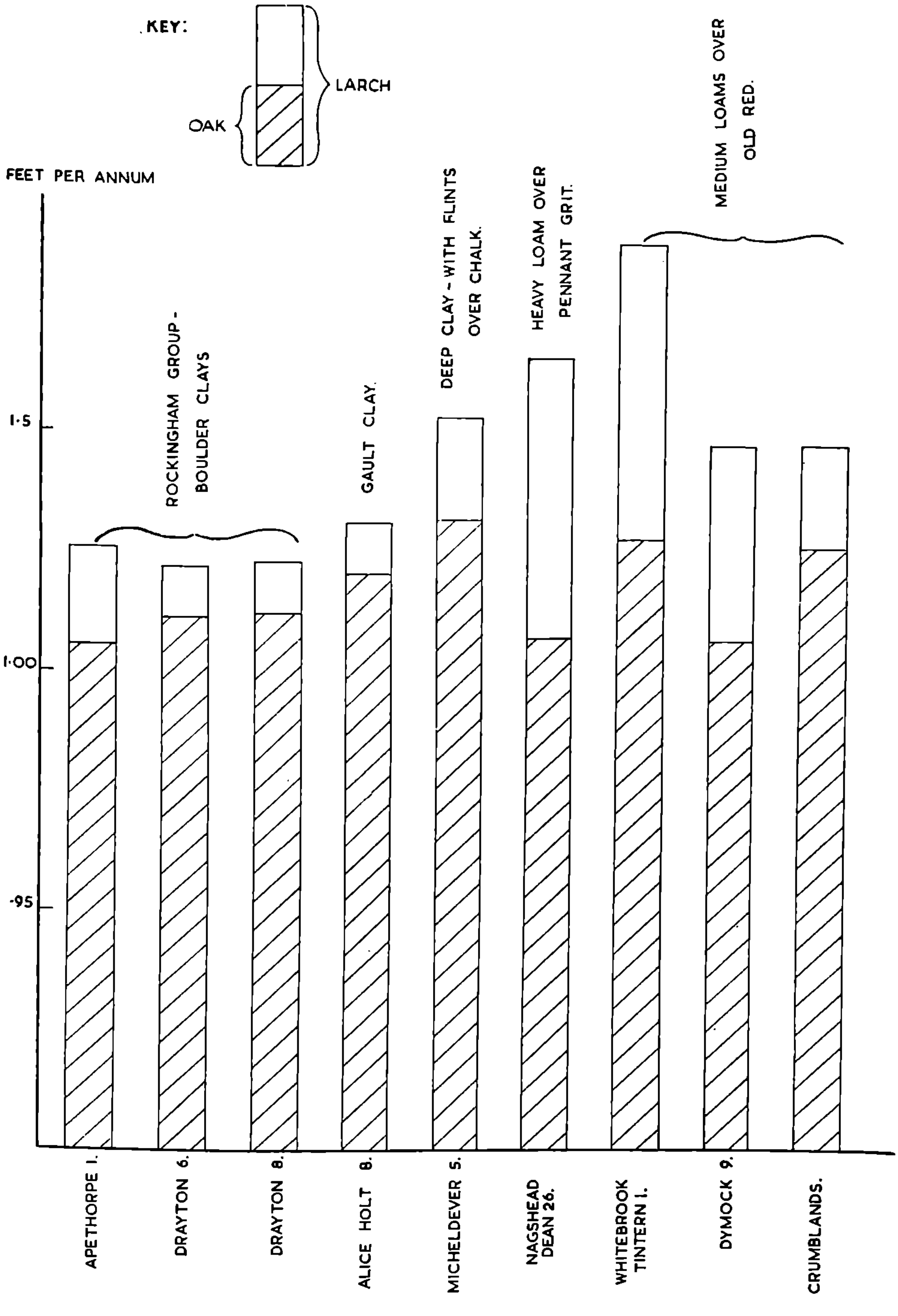

Fig.2. MEAN ANNUAL HEIGHT INCREMENTS OF LARCH AND OAK IN EVEN-AGED MIXTURE

The nursing effect is probably largely due to the influence of shelter on the water economy of the oak. It is not thought that diminished root competition has much to do with it, though inspection has shown that the zones of rooting of the two species are quite different.

Composition of Crops at Early Pole Stage, Thinning, and Initial Yields of Larch

Composition of Crops

The majority of the plantations have reached the stage for first thinnings in the larch. Generally speaking the onset of thinning in the larch has been dictated by the requirements of the oak, though in the strip mixtures the larch itself has required thinning at about the same time as it has appeared necessary to free the oak.

Quite apart from the original stockings adopted, there are considerable variations in the stands of larch due to early losses. These have been greatest, as would be expected, on weedy old woodland sites, several of which are also subject to severe frosts (e.g. Micheldever).

Prior to thinning, plantations ranged in their stocking of larch between 288 and 480 stems per acre, but there was a good deal of irregularity inside plantations.

The 16 ft. centre-to-centre groups at Micheldever have been carefully studied to discover whether there is any depression of the oak associated with the full development of all originally planted larch adjacent to a group. No suggestion of this was found.

These plantations do not of course tell us what is the maximum stocking in numbers or basal area of larch, at the first thinning stage, compatible with an adequate distribution of young oak, because although we have good oak in all the treatments attemptea, we cannot be sure how it will develop in the later stages when the crops are truly mixtures. This condition will be reached first in the group methods; in the strips, particularly the broader ones, we shall have competition between oak and oak for considerably longer.

Thinning

While each crop has its own problems, there is one broad question common to all the mixtures, how much larch can we keep to saw-timber dimensions without injuring the prospects of the final oak crop? This is being investigated at Crumblands and elsewhere, and it seems probable that the answer will not be the same for each type of mixture. The type of larch to be retained is also of importance; in some plantations we have a very clear choice among the larch of desirable form between strong dominants and much less vigorous individuals. The former will produce saw-timber many years sooner, but are likely to be awkward constituents of a mixed crop.

Initial larch thinnings in three types of mixture at Crumblands, all governed specifically by the requirements of the oak, yielded the following quantities:—

LARCH THINNINGS FROM OAK MIXTURES AT CRUMBLANDS, TINTERN FOREST

Table 18

Type of Mixture	Larch Thinnings Removed	
	No. per acre	Vol. Hoppus feet over bark per acre
Strips, 6 Oak/3 larch	42	92
Strips, 4 Oak/2 larch	110	265
Groups at 18 ft. centres	132	346

Allowing for the difficulty in defining a common thinning method for mixtures of different arrangement, these differences probably reflect the degree of intimacy of the mixtures; the two latter methods have the greater proportion of larch in contact with oak.

Little thinning of oak in groups and strips has so far been necessary. In the groups it is usually only necessary at this stage to favour one well formed dominant, or perhaps two if there is doubt as to the choice. This is purely a crown thinning, there being no need to touch subdominants and suppressed stems.

SURVEY OF PLANTATIONS ON OPENCAST IRONSTONE MINING AREAS IN THE MIDLANDS

By R. D. PINCHIN
Assistant Silviculturist

A survey was carried out of plantations on worked-out opencast land in the iron-ore fields of the Midland counties. The main commercially workable areas are situated in the northern half of Northamptonshire, North and South Lincolnshire, East Leicestershire, Rutlandshire, North Oxfordshire and South-east Warwickshire. About 20,000 acres of land have been worked for midland ores, particularly in Northamptonshire, from Roman times, and until recently restoration to agriculture was carried out. The necessity of working deeper over-burdens, however, has brought about the introduction of heavy mechanical excavating machines which leave the land, after quarrying, in the form of large continuous furrows and ridges locally known as "hill and dale".

Geology and Soils

The solid geology of the area with which the survey is concerned is of marine origin, and consists of the Inferior Oolite and Great Oolite of the Jurassic Formation, laid down in the Mesozoic Period. Two ages of rock are present, the younger being Great Oolite Limestone and the older the Lincolnshire Limestone, each of which is underlain by beds of sands, clays and silts of varying thickness and composition, termed the Upper and Lower Estuarine Series respectively. The whole rests upon the Northampton Sand, a very variable series of sandy deposits, in the topmost strata of which the iron ore occurs as deposits of chamosite (iron aluminosilicate) and siderite (iron carbonate) from six to twenty feet in thickness.

Resting upon the solid geology, a cap of clay of very varying thickness is frequently found, usually consisting of glacier-borne boulder clay, but also, in the south, of Great Oolite Clay.

The limestone attains a maximum thickness of about forty feet, the Estuarine Series forty-five feet, and the boulder clay forty feet, all strata being intimately mixed during the process of quarrying.

Some of the limestones are hard and resistant to weathering action; others consist of feebly-cemented shells, sand and oolites which rapidly weather down. The Estuarine deposits, too, vary considerably ranging from fine, impervious clays, through shales and silts to coarse sands. Further complication is added to the soil problem by the considerable local variation in the strata.

Afforestation

Of the total area of land worked for ironstone, over 6,600 acres have not been restored to agriculture, and of this about 1,035 acres have been utilised for afforestation since the beginning of the century.

The most important plantations are to be found in the neighbourhood of Corby (547 acres), Kettering (191 acres), Wellingborough (169 acres), and Thrapston (112 acres). Most of the commonly planted forest tree species, both indigenous and exotic, have been used as well as some ornamental species.

The purpose of the survey was to assess the value of the various species on the different soils of the ironstone workings from a study of their past history, growth and general development.

Method of Survey

A soil classification was carried out on each plantation site, by inspection of trial boring records and adjacent quarry faces, in conjunction with surface examination by means of soil pits. Small sample plots representing, as far as possible, different species and ages on the most important types of soil, were then assessed for the chief characteristics both of the crop and of the site.

Summary of Results

The general policy pursued in the past, with certain exceptions, has been to plant conifers on the lighter soils derived from sands and limestone, and hardwoods on the heavier soils with a high clay content. This has proved, on the whole, successful.

EUROPEAN LARCH

This species has been the most widely used and also the most successful generally, except where impervious clays constitute more than about seventy per cent. of the soil, when growth is seriously retarded and losses are correspondingly high. In the worst instances, height growth may be as little as 2.5 feet at fourteen years, as, for example, on the Estuarine clay of the Wellingborough area and the blue-grey Boulder Clay of the Corby area.

Larch has shown the best growth on limestone-derived soils in the Kettering (Boughton Estate) and Corby areas, particularly where clays or silts constitute approximately twenty to fifty per cent. of the soil. The best of the older plantations average Quality Class III, but the vast majority are only Quality Class IV, which would appear to be the most one could expect in the first rotation.

Larch is not suited to the extremely sandy soils, nor is its growth noticeably improved by planting in replaced topsoil.

It has been used extensively in the Corby area in recent years in mixture with sycamore and pine, and is observed to be more sensitive to soil changes than sycamore.

In older plantations it has often suffered from wind-blow through shallow rooting, but appears able to withstand smoke injury.

JAPANESE LARCH

This species shows the same general requirements as European larch and in the majority of plantations has attained Quality Class III. Its rate of growth on all soils is faster than that of European larch in the early years, but, in later years, it is often exceeded by that of the European species.

HYBRID LARCH

The results obtained in a plantation of hybrid larch, planted in 1930 at

Boughton Estate, indicate that its growth on limestone-derived soils may be more rapid than that of European or Japanese larch. In the early years it is faster in growth than European larch on clay soils near Corby, and might profitably be put to a much wider use on worked land.

SCOTS PINE

Scots pine has grown satisfactorily on all but the stiffest clay soils, some older plantations having attained Quality Class III on the best sites.

On extremely sandy soils it is greatly superior to European larch. Being fairly accommodating in its requirements, it has been planted extensively in mixture with European larch and sycamore, on soils consisting of mixed limestone, clay and sand in the Corby area. It appears windfirm on all sites, but its crown is often damaged by exposure.

CORSICAN PINE

This species has been used in mixture with European larch and sycamore on all types of mixed soils in the Corby area since 1945. Though slower than larch in getting away, it appears healthy and well established, with few losses, even on clay-dominant soils.

Older plantations of this species show a rate of growth and volume of timber production higher, generally, than other coniferous species, and it can safely be recommended for more extensive use, except on areas of stiff pure clay.

NORWAY AND SITKA SPRUCES

The spruces have been little used for the afforestation of ironstone workings. On stiff clays both species have suffered prolonged check, but they appear to thrive better on the lighter, limestone-derived soils. They are, however, unlikely to make better than Quality Class IV growth even with careful site selection.

DOUGLAS FIR

The few lots available for study indicate that this species is unsuited to the soils and climate of the area.

SYCAMORE

Sycamore has, with larch, proved itself the most successful species on all types of soil and has been used extensively in mixture with larch and pine since 1944. On the lighter, limestone-derived soils it has attained Quality Class II, but on the heavier clay dominant soils it averages quality Class III. Slow in growth in the early years, but with few losses, it is wind-firm, drought and smoke resistant. This species can therefore be used with some confidence as a pioneer on all types of soil.

ASH

Ash, though much used in early plantations, has not succeeded as a pioneer, and has only grown well in occasional groups where the soil is very moist, or on replaced topsoil. It suffered severe losses in the early years from rabbits, frost and drought, and, in mixture with European larch, from suppression.

OAK

Common oak has suffered heavy losses, and has grown poorly except on replaced topsoil, and it is therefore of doubtful value for the afforestation of ironstone workings.

BEECH AND HORNBEAM

These species have been tried in mixture as soil improvers, but have suffered from suppression by faster growing species.

ELM

The wych elm has shown rapid growth and excellent form, mainly on soils derived from the Estuarine beds and on restored topsoil. On account of serious losses from the Elm Disease, however, it may not be safe to use it, except on a limited scale, unless resistant strains are available.

OTHER HARDWOODS

Black Italian poplars, and the grey and common alders, have shown rapid growth on all types of soil and have done better as pioneers on the stiff clays than any other species. They have, however, suffered from wind-blow and die-back at twenty to forty years of age. The poplars are unsuitable in mixtures, on account of their more rapid rate of growth.

Robinia pseudo-acacia was tried in early plantations but has not succeeded.

Trial planting

Trial planting of the following species, on a small scale, has been undertaken since 1948 in the Corby area:

Norway maple, birch, Japanese crab apple, Japanese cherry, rum cherry, common cherry, *Prunus pissardi*, whitebeam, cockspur thorn (*Crataegus crus-galli*), laburnum, red oak, lime, hornbeam, walnut, plane, sweet chestnut, elm, *Abies nobilis*, *Thuja plicata*, Sitka spruce and Douglas fir.

Losses among the hardwoods have been low, whereas losses among the conifers have been high, particularly on the boulder clay soils.

Pests and Diseases

In general the plantations are free from serious fungal and bacterial disease, although many of the elms have been lost through the Dutch Elm Disease. The fungus *Dothichiza populea* has also caused injury and losses to Black Italian and Balsam poplars, while ash has suffered stem deformation due to the canker bacterium *Pseudomonas savastonoi* on some unsuitable sites. Larch appears to be very little affected by canker or die-back. The leaf-scurf fungus, *Rhytisma acerinum*, is common on sycamore, but has little apparent ill-effect.

Effect of Aspect

A study of the effect on growth of planting on north and south aspect was made on the "hill and dale" in the Corby area. The results indicate that in the case of sycamore, Scots pine and European larch, growth tends to be better on south than on north facing aspects.

DERELICT WOODLAND INVESTIGATIONS

By A. D. MILLER
Assistant Silviculturist

Classification of Derelict Woodlands

Figures compiled during the Census of Woodlands show that the total acreage of derelict woodlands in the Southern English hardwood area is very considerable; although these figures show the various silvicultural types of derelict woodlands, this information is not, in itself, sufficient to ensure that research is concentrated on the more important types, because in many cases the treatment given to these woodlands must depend on the geology and soil types, and the Census gives no indication of the way in which silvicultural types are distributed over the different edaphic types.

Therefore it was decided to re-classify the Census information on the broadleaved derelict woodlands in the South-East England and South-West England Conservancies, to discover the total acreage of unproductive woodland on each geological formation, so as to show which kinds of derelict woodlands occur most frequently on each soil type, and where the bulk of research work into the problems of rehabilitation should be directed. It was decided, arbitrarily, to include as "Derelict" all woodland listed by the Census as follows:

(1) Scrub
(2) Devastated broadleaved forest
(3) Simple Coppice, other than pure chestnut coppice
(4) "Coppice-with-Standards" with "Bad" stocking assessment of standards, or where remarks indicated that the area was in a neglected condition.
(5) Broadleaved High Forest where stocking was assessed "Bad".
(6) Areas Felled before 1939.

There is no indication in the census of whether coppice is worked or not, and it was decided that coppice which is being regularly worked could not justifiably be termed derelict. On the assumption that all pure chestnut coppice was being worked, or could be worked profitably, it was excluded from the derelict lists.

The main species occurring in mixed coppice are chestnut, hornbeam, birch, hazel, ash, and oak. It was found that chestnut is utilized intensively whenever it forms a reasonable proportion of the mixture. Other species, particularly ash and oak, may be cut with it, but where the proportion of chestnut is low, or non-existent, the coppice is usually unworked. On this basis it has been assumed that ten per cent. of the mixed coppice may be classified as not derelict, and this has been deducted in the summary.

Having extracted the list of Derelict Woodland for one county, each site was identified on the census map photographs, and in turn, on the corresponding geological drift map. Where six-inch geological maps exist, a high degree of accuracy was obtained in identifying each site with its geological formation. Using one-inch maps the accuracy was less. Where sites were on more than one formation, this was noted in the lists, but in the county summaries they were classified according to the predominating formation.

Each silvicultural type, comprising more than 200 acres on any one geological formation, was selected for sampling in the field. Of each type selected, two sites were chosen from the list of derelict woodlands, taking into account distance, accessibility and acreage. These sites were visited and the geology, soil, and vegetation were noted and some generalisations made regarding tree species, ground vegetation, and soil likely to be found on the different formations.

It was found in these Southern districts, where the effects of glaciation have generally been small and boulder clay is absent, that a very good idea of the type and condition of the soils in any particular area could be gained by studying the geological drift maps. The only exceptions were areas marked on the maps as chalk, which might carry very dry soils only a few inches deep, or good moist soils 1½ feet or more in depth, but because this re-classification was concerned only with old woodland areas, all the sites classified as "Chalk" in fact carried at least ten inches, and frequently more of fertile loam, and were capable of supporting good beech.

On the majority of derelict woodland sites it was found that the species which formed the previous crop had been well suited to their site, and many of the conditions existed which should have favoured natural regeneration. In spite of this, self-grown seedlings of oak and beech were found only rarely;

of the other common species, birch, ash, sycamore, and to a lesser extent sweet chestnut, often regenerate copiously. Birch regeneration was found on all formations, most dense and vigorous on the sandier soils and least on the chalk. Ash had regenerated on the chalk and clay with flints, and on the heavier clays, where, however, it does not thrive. Sycamore regeneration was found on the more fertile soils of the chalk and clay-with-flints, and to a lesser extent on the clays. Chestnut regeneration was less common, occurring chiefly on the more fertile sands.

The principal factors which reduce the amount of successful natural regeneration on derelict woodland sites appear to be:—

1. The small number of parent trees.
2. The presence of dense shrub and weed layers.
3. Adverse local soil conditions, compaction and drying out of the soil surface usually resulting from timber extraction and allied operations.
4. Destruction of seed and seedlings by vermin, which usually abound on neglected sites. There seems to be little doubt that in many places this is the critical factor, and that given adequate protection a useful number of natural seedlings would appear on most old woodland sites.

The following summary showing the number of acres of each derelict woodland type in the South-East and South-West Conservancies, and their distribution over the principal soil types, has been made from the detailed county lists showing all the geological formations, and the areas of derelict woodland occurring on each.

It will be seen that the total area of scrub greatly exceeds that of any other silvicultural type, while the most important soil type is the "fertile and moderately fertile loams and permeable soils" which carries more than twice the area of derelict woodland than the heavy clays, which give the next highest total; the total of coppice and coppice-with-standards on calcareous soils is low.

SUMMARY OF DERELICT BROADLEAVED WOODLAND IN THE SOUTH-EAST AND SOUTH-WEST CONSERVANCIES OF ENGLAND

Table 19 Areas in acres

Type of Soil	Scrub	Devastated Areas	Felled Areas	Simple Coppice	Coppice with Standards	Broadleaved High Forest	Total
Chalk and Great & Inferior Oolites	14,635	5,341	6,425	7,314	4,040	2,132	39,887
Heavy Clays	12,849	7,244	3,690	19,313	8,115	3,131	54,342
Fertile & Moderately Fertile Loams and Permeable Soils	37,795	18,903	32,288	15,573	4,753	7,484	116,975
Infertile Soils	8,577	6,833	4,477	3,494	2,955	2,539	28,515
Peat & Alluvium	2,112	220	44	471	30	348	3,406
TOTAL....	75,968	38,541	46,924	46,165	19,893	15,634	243,125

Note:—The South-East Conservancy comprises the Counties of Kent, Surrey, London, Middlesex, Sussex, part of Hampshire, and Berkshire.
The South-West Conservancy comprises the Counties of Cornwall, Devon, Somerset, part of Dorset, Wiltshire, part of Gloucestershire, Worcestershire, and the greater part of Herefordshire.

Rehabilitation of Derelict Woodland—Weston Common Demonstration Area, Alton Forest, Hants.

The rehabilitation of the fifty-acre demonstration area has been proceeding as laid down in the working plan which was completed in September, 1950.

This woodland had once carried a mature hardwood crop, which was devastated during the ten years immediately following the first world war; since then it had suffered the consequences of silvicultural neglect, but in spite of this, dense natural regeneration of ash and sycamore, dating from the late 1920's, had sprung up over most of the area, but this had suffered very severe damage by rabbits and grey squirrels.

At the time when the working plan was written, forest conditions prevailed over most of the area, the two significant elements of the crop being the remnants of the old crop which the timber merchants had not thought worth cutting, and the twenty-year-old pole crop of dense natural sycamore and ash, which in some places was too badly damaged to be acceptable.

The working plan lays down four prescriptions which are to be used in converting this area to an economic woodland with the minimum of labour and expense, and at all times conserving valuable stems which show prospect of getting into the canopy. The prescriptions are:—

1. Cut all the scattered remnants of the old crop which will yield enough produce to pay for their removal; those trees which it would not pay to cut will be girdled.
2. In groups where the young poles are too badly damaged to be allowed to grow on, they will be cut and allowed to coppice; the coppice stools will be singled later, and the best shoots tended to form a crop.
3. In groups where the damage to the young poles has been relatively light, they will be thinned and accepted as part of the crop.
4. Bare areas to be planted with beech.

The initial work of preparing the ground has been finished in two of the three compartments which form the demonstration area, and the old standard trees have been extracted and sold. The costs of all operations have been kept very carefully and the following financial statement has been drawn up for compartments 1 and 2 which cover 37.7 acres.

EXPENDITURE AND RECEIPTS OF REHABILITATION WORK, COMPARTMENTS 1 AND 2, ALTON FOREST

Table 20

Expenditure	£	Receipts from Sales	£
Felling, cross-cutting, extraction	761	Firewood, including young poles and cordwood from felled standards	302
Burning tops, preparing cordwood	601	Produce from Yew Trees....	96
Treating the young pole crop, including cutting back badly damaged groups and thinning acceptable groups	157	Timber	2,482
Felling yews and preparing produce	173		
Miscellaneous, including forest protection work and wet time	180		
	1,872		
Balance, being excess of Receipts over Expenditure	1,008		
TOTAL	£2,880		£2,880

In the autumn of 1950 there was a liberal beech mast, which gave promise of adequate natural regeneration to restock the newly bared areas, but this has not been realised. Relatively few viable beech seeds remained in the spring of 1951, and the number of beech seedlings on the ground is disappointingly small, so that the area cannot yet be considered as fully stocked. Until a detailed survey has been made of the way in which natural seedlings are colonizing the bare areas, it will not be possible to say how much of the 37.7 acres in the first two compartments will need to be planted, but the figure may well be in the neighbourhood of seven acres; the cost of this planting will, in due course, be subtracted from the present balance in hand of £1,008.

For a trial period, large spreading yews were felled on piece rates, and the limbs converted into stakes or gateposts, or sold as firewood, and after some difficulty the large butts were sold as timber. In spite of disposing of all the produce at more or less favourable rates, this method of dealing with the yews resulted in a loss of about 10/- per tree, and has been abandoned. Yews are now being dealt with either by being "laid in" (or ringed with axe-strokes) at the butt, or where convenient the slash from newly felled standards is piled round the butt and burned; each of these methods costs 1/- per yew.

The Use of large Transplants for Enriching Partially Stocked Areas

In Compartment 6, a part of Weston Common reserved for experimental work, a trial planting has been made using beech trees eight to ten feet high, to enrich an area already carrying a certain amount of growth, which with adequate tending could be formed into a crop. These large transplants were widely and rather unevenly spaced through the existing growth, but the aim will be to produce a mixed crop in which potentially valuable stems are never spaced at more than 20 ft. x 20 ft.

It was found that 80 big beech were necessary to achieve the desired stocking over the whole 10.7 acres of Compartment 6, and that the costs of pit planting each tree individually, securing each to a stake, and mulching around the stems amounted to £8 in all, or 2/- per tree, exclusive of cost of the tree itself. The planting was done carefully, and it seems certain that all except two or three trees will grow satisfactorily. In spite of the fact that most of this compartment is now a sea of bracken 6½ feet high, no weeding has been necessary, and it seems likely that the future tending of these plants will consist only of pruning the crowns to maintain a single axis, and pruning the lower stem to ensure an adequate length of clean saw log.

Conversion of Hazel Coppice to Beech High Forest

As a result of earlier work on the conversion of uneconomic coppice systems, a good deal of evidence has been accumulated about the silvicultural methods most likely to be successful. It has long been known that some of the methods which aim at reducing the costs of conversion, by doing a minimum of clearance and planting, are likely to involve weeding and cleaning for a very long time before the planted crop is safe from competition by the uncut matrix; but opinions differ as to how the initial economies compare with the increased costs in later years.

Because there are large areas of uneconomic coppice in this country which at sometime will have to be converted to High Forest, it is desirable to have a reasonably accurate picture of the relative costs of different methods of conversion; therefore it was decided to lay down a properly replicated and carefully costed experiment, with the objects of comparing the costs involved, and the timber crop produced, by the principal methods of conversion which were known to be silviculturally sound.

A suitably homogenous area was found at Gardiner Forest, Wiltshire, where the growing stock consisted mainly of neglected hazel coppice thirty to forty years old with occasional ash and field maple stools, a few natural birch of the same age, and very occasional (about one to every two acres) old branchy standards of oak and beech.

The dense shade cast by this type of canopy produced a forest floor that was relatively free from both bracken and brambles; this not only made the work of preparing the ground more than usually straightforward, but should mean that the costs of weeding will be small, at least until these weeds become established; in fact weeding in the early years will be governed only by the necessity to cut back regrowth from the coppice stools. Five different methods of manipulating the old hazel coppice were selected; they were:—

(*a*) Cutting large irregular gaps roughly 30 feet square out of the hazel matrix, with nowhere more than 12 ft. of uncleared coppice between adjacent gaps. 25 beech were planted in each gap in groups of 5, giving an average of 625 trees per acre.

(*b*) Cutting small but irregular gaps about 12 ft. square and spaced at roughly 21 feet centres, but allowing some latitude in the matter of spacing so as to take advantage of any natural openings in the canopy. 5 beech were planted per gap, giving an average of 490 trees per acre.

(*c*) Cutting strips 12 ft. wide and leaving 10 ft. of uncleared coppice between strips. Two rows of beech were planted per strip, spaced at 4 ft. x 3 ft. and giving an average stocking of 987 trees per acre.

(*d*) Thinning the hazel so as to leave a light but uniform canopy under which beech were planted throughout at approximately 4 ft. x 4 ft.; the mean stocking for this treatment was 2,540 beech per acre.

(*e*) Complete clearance of the coppice and planting throughout with beech at approximately 4 ft. x 4 ft., which produced a mean stocking of 2,532 beech per acre.

The choice of these five treatments, and the particular sizes of the groups and strips, was based on an appreciation of earlier work in converting similar woodlands, and each treatment was selected as being about the best of its kind. The object of each treatment was to produce eventually a fully stocked beech plantation.

The layout of the experiment was seven replications of each treatment in random block design, each plot being half an acre.

It appears that the cost of preparing ground, which constitutes the greatest proportion of the initial costs in this type of conversion, depends very largely on the methods of disposing of the cut coppice material, and the first block was used to obtain experience, and to discover the most economic way of dealing with the cut coppice in each treatment; costs from this test block are not included in the mean values shown below.

After a certain amount of trial and error, it was found that laying the cut material amongst the uncut coppice was always cheaper than burning it, and that this was possible in both sizes of groups and in the strips; in trial strips 18 feet wide, leaving 10 feet of standing coppice, there was too much cut material to be laid, and this was one factor which contributed to the choice of 12 foot strips. In the "Thinning for underplanting" and "Clear cut" treatments there was so much cut material that it had to be burned, and this was one cause of the high costs of these two treatments.

The selected method of dealing with the cut coppice was applied in five blocks, and the initial costs incurred are summarized in Table 21, below. In order to be able to compare the costs of the various treatments, all operations were carefully timed, and costs were estimated on the basis of 2/- an hour for labour. These costs cover only the work done within the area of each plot;

the costs of the plants have been calculated at the rate of £5 per 1,000, which represents the costs of producing them, but does not include the costs of transport from the nursery nor of miscellaneous handling before planting.

INITIAL COSTS PER ACRE OF CONVERTING OLD HAZEL COPPICE TO BEECH AT GARDINER FOREST

Table 21 .... Mean Values from 5 Blocks

	Large Groups	Small Groups	Strips	Thinning and Underplanting	Clear Cutting
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1. Preparing ground	13 15 0	9 15 0	16 11 0	23 5 0	30 18 0
2. Cost of plants	3 2 6	2 9 0	5 2 6	12 14 0	12 13 0
3. Cost of planting	17 0	12 6	1 11 0	4 10 0	4 2 0
TOTAL	17 14 6	12 16 6	23 4 6	40 9 0	47 13 0

In one block all saleable produce was prepared and stacked in a corner of the plot from which it had come, and the value of this produce was estimated separately for each treatment; this seems to show that where a market exists, or can be created, the cash returns from the produce yielded by apparently unattractive old hazel coppice are surprisingly large. It is not possible to compare accurately the costs of extraction in the different treatments, because in order to reach a ride the produce would need to be carried through plots of different treatments; however the fact that the costs of preparing produce included stacking in a corner of each half-acre plot, means that to some extent they reflect the fact that it is more difficult to extract through groups than through strips or clear cut areas. The various costs and the value of the produce are shown in Table 22, while details of the amounts and value of the produce are shown in Table 23, but of course these are applicable only to this type of woodland; in other areas carrying a different original stocking the values of the produce would almost certainly vary widely from those shown here, for instance where the matrix carries a good deal of birch the cash returns from produce tend to be much higher than from pure hazel coppice.

INITIAL COSTS AND VALUE OF PRODUCE IN CONVERTING OLD HAZEL COPPICE TO BEECH AT GARDINER FOREST

Table 22 Values from One Block Only

	Large Groups	Small Groups	Strips	Thinning and Underplanting	Clear Cutting
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1. Preparing ground and preparing produce....	17 7 0	14 7 0	19 9 0	31 9 0	40 10 0
2. Cost of plants	3 2 6	2 9 0	5 2 6	12 14 0	12 13 0
3. Cost of planting	17 0	12 6	1 11 0	4 10 0	4 2 0
4. Total Cost	21 6 6	17 8 6	26 2 6	48 1 3	57 5 0
5. Value of produce	12 1 0	12 14 0	15 12 6	15 6 0	32 3 0
6. Net cost (subtracting 5 from 4)	9 5 6	4 14 6	10 10 0	33 7 0	25 2 0

AMOUNT AND VALUE OF PRODUCE PREPARED PER ACRE FROM COPPICE AT GARDINER FOREST

Table 23

Type of Produce	Large Groups		Small Groups		Strips		Thinning		Clear Cut	
	No.	£ s. d.	No.	£ s. d.	No.	£ s. d.	No.	£ s. d.	No.	£ s. d.
1. Bean rods. Bundles of 25 at 2/6d.	12	1 10 0	24	3 0 0	20	2 10 0	40	5 0 0	34	4 5 0
2. Pea sticks. Bundles of 30 at 1/6d.	16	1 4 0	26	1 19 0	42	3 3 0	34	2 11 0	42	3 3 0
3. Plant sticks. Bundles of 50 at 3/-	8	1 4 0	10	1 10 0	11	1 13 0	18	2 14 0	14	2 2 0
4. Maple fencing stakes. 1/- each	88	4 8 0	50	2 10 0	29	1 9 0	26	1 6 0	128	6 8 0
5. Firewood. 25/- per cord	3	3 15 0	3	3 15 0	5½	6 17 6	3	3 15 0	13	16 5 0
6. Fire broom handles. Not saleable*	83		46		15		60		50	
TOTAL		12 1 0		12 14 0		15 12 6		15 6 0		32 3 0

Note: * Used for forest protection.

Studies of the Early Growth and Form of Beech

An intensive study was made at Gardiner Forest, Wiltshire, of the factors affecting the growth and form of young beech which had been planted in 1946, being introduced into an area of old hazel coppice in different sizes of strips and groups.

The soils were generally shallow loams over chalk, and where the beech were growing in sheltered conditions with a normal woodland flora the growth had been very good, but in areas where the young trees had been a little exposed to south-west winds, and where the ground vegetation consisted mainly of dogwood and privet, the growth of beech had been very poor. One object of the study was to find out which of the environmental factors were responsible for the very marked differences in growth between the various localities.

A study was also made of the form of a large number of the same beech, which were classified according to their relative fineness of branching and whether or not they had developed a definite fork. The incidence of Lammas shoots, and of damage to the leading shoot, was also observed at each locality.

The following conclusions were reached:—

(1) That variations in the soil depth, from three feet down to ten inches over the chalk, had no effect on beech growth up to this stage of development.

(2) That even after a long dry spell in mid-summer, these shallow soils contain enough moisture to permit growth, but that soils associated with hazel shelter and an herbaceous flora are slightly more moist than those associated with privet, dogwood, sedges and grasses.

(3) That the shelter provided by hazel coppice has little effect on soil temperature.

(4) That root competition with privet and dogwood can be a critical factor in determining whether or not transplants become established

satisfactorily, especially if the young trees are also exposed to wind, but that root competition from hazel and scattered ash standards is not injurious to beech.

(5) That the light intensity falling on beech crowns, measured as diffuse light, can be reduced to about one half of full daylight without causing any loss of vigour in trees of this age.

(6) That hazel hedges separating groups and strips of beech cannot be relied on to give protection from early autumn frosts.

(7) That hazel hedges provide considerable shelter from wind, and that one very important effect of this is the reduced transpiration stress to which the beech are subjected. Standard evaporimeters, placed at exposed sites, lost about ten times the amount of water per week which was lost by evaporimeters at sheltered sites. The suggestion is that on sites where water supply is not abundant, the increased water loss from the leaves of trees on exposed sites would cause a state of water deficiency, and hence reduced photosynthesis, with consequent lesser height growth; while trees with a similar water supply, but in a sheltered position, would not suffer the same water loss, so that photosynthesis and growth would proceed normally. One would expect this effect of shelter to be most marked where the soils tend to be dry, but that where there is a liberal supply of water even exposed trees would be able to maintain an adequate transpiration flow, so that there would be no reduction in photosynthesis. Ordinary observation tends to support this idea, but more work is needed to clarify the effects of shelter on the water economy of trees.

(8) That there was no significant difference in the incidence of forks between sites receiving nearly full daylight and those with varying degrees of shade, but that an incipient fork was less likely to develop permanently if the tree were in a shaded position.

(9) That the occurrence of forks in beech is closely related to the incidence of leading shoot damage, and that Lammas shoots are an important source of leading shoot failure.

(10) That, for reasons which are not altogether clear, the form of the beech in the smaller groups was better than that in the large groups, irrespective of variations in light intensity.

INFLUENCE OF SHADE ON THE HEIGHT GROWTH AND HABIT OF BEECH

By J. M. B. BROWN

Forest Ecologist

The main objects of these investigations are:—

(*a*) To determine how far the light can be reduced without adverse effect on the height growth of young beeches.

(*b*) To elucidate the effect of shade on the habit of the tree and the tendency to fork.

Other points to which attention is being given are the influence of shade on dry weight increase and on root-shoot ratio, and the minimum relative light intensity for survival and healthy growth in the forest.

In all observations, measurements of light intensity were made by means of the Selenium photo-electric cell and expressed as *relative light intensity*; i.e. percentage of the full light intensity received in the open at the place and time. The actual measurements were taken in foot-candles, but no attempt has been made to summate the light received in a given environment over a period of time, nor to determine absolute values related to survival, rates of increment and habits of growth of beech. The response of beech to shade is being studied, both in the forest and under artificial screens in the nursery. Very satisfactory screens were provided by plasterer's laths supported in a parallel row at an empirically determined spacing on a wooden frame. A second row of laths at right angles to the first furnished a deeper shade, but for the heaviest shade (5 per cent. of daylight was aimed at) it was necessary to use hessian. This was less durable, and had the disadvantages of intercepting much light rain and of showing some slight variation in light transmission in accordance with the weather: but it served the purpose adequately.

The work is still in progress, but some interim results are worth putting on record.

Height Growth

The observations under experimental shade in the nursery were made on beech seedlings which had been transplanted in February, 1950. Little growth in height was made in 1950, and the differences between the treatments were insignificant; the better average performance of the control plants in the open was accounted for by the greater frequency of late summer (Lammas) extension. Such Lammas growth was rare on the (strongly) shaded plants. Plants in the open shed their leaves rather earlier in November, 1950, and resumed growth distinctly later in the ensuing May. A full assessment of height increment, dry weights of shoot and root, leaf number, and size and habit of growth, will be carried out in the autumn of 1951. There are three degrees of shade, cutting off approximately 50%, 80% and 95% of the light reaching the controls: each treatment has six replications.

In the forest, observations have been made on young beeches growing in different degrees of shade, and on beeches of the same age growing in otherwise similar conditions in the open. In Friston Forest, Sussex, Compartment 24, beeches growing in a light intensity of 20-25% of full daylight, under the shade of 22-year-old pines, were found to be making annual increments at least equal to those of beeches in the open on the same soil nearby. Under heavier shade, where the mean relative light intensity was 9.5% (range 6 to 13 per cent.), the leading shoots were shorter and strongly inclined from the vertical. A relative light intensity of about 17 per cent. was recorded at the base of the leading shoots of beeches growing in the shadow of vigorous fifteen-year-old larches planted at the same time in Cirencester Park, Glos. Measurements of recent height increments of the beeches failed to show any fall-off in the last year or two, but the tips were somewhat inclined from the vertical, and it is probable that the light intensity was critical. In Eartham Wood, Sussex (Slindon Forest, Sussex, Compartment 6) a good comparison was obtained between beeches growing under a light canopy of birch and ash, and beeches of the same age (10 years) which had been relieved of all overhead shade four years before. Photo-electric measurements showed that the shaded trees, of which the current height increments were better than those of the unshaded trees, were receiving about 30 per cent. of full daylight. Locally, however, the shade was deeper and, near a small beech tree, through which only 5 to 10 per cent. of the daylight penetrated, growth had been much slower than in the open. Some observations in Gardiner Forest, Wiltshire, also indicated that a relative light intensity of 5 to 10% is adverse to the height growth of young beeches in the forest.

These observations, which are being confirmed and extended, are in good agreement in indicating that the critical light intensity for the height growth of beech in Southern England lies between 10 and 20 per cent. of full daylight. Below 10%, "table topping" and reduced increment are almost invariably noted: where the relative light intensity exceeds 25% and probably at all intensities above 20%, height increment appears to be not inferior to that of beech in the open. It seems likely that a slight stimulation of height increment at light intensities between 25% and 50% of full daylight will be confirmed. This is, of course, much above the light intensity prevailing in any fully stocked mature wood in summer: under beech 98%, or even more, of the daylight may be cut off.

Habit of Growth and Forking

Consideration of the effect of shade on the forms of young beech trees must take account both of the direct and of the indirect results. Inasmuch as other environmental factors are doubtless concerned in the production of each effect, the distinction may not be strictly logical: but it is important to separate those results in which reduced light appears to be certainly involved, from those which are incidental to the shelter, or to the direct results. Such are the results which can be ascribed to the milder fluctuations in temperature and humidity, or to increased attack by insects, etc., which find the shade environment congenial, and less attention from those which affect sunny sites.

The direct effects which have been noted are manifested in:—

(1) The direction of the leading shoot.
(2) The dimensions of the shoots.
(3) The habit of branching.
(4) The size of the leaves.
(5) The tendency to late summer shoot extension.

The observations made will be briefly summarised under these heads.

(1) Under fairly uniform shade, the erect growth of the leading shoot is not affected until the relative light intensity falls below about 20%. In a light intensity of 10% or less, the leading shoot is markedly horizontal: in light intensities between 10% and 20% various degrees of inclination from the vertical are noted. It is possible that the horizontal growth of the leading shoot is conditioned rather by the relation between side light and overhead light, than by the absolute value of the overhead light: this possibility has not been examined yet. Where the overhead canopy is locally variable, the tips of beeches commonly grow towards a break in the canopy: this may result in a sinuous stem in the older tree.

(2) The shoots of shaded beeches are thinner and weaker, though often longer, than those of open-grown trees. They are also more conspicuously pendulous when immature and, in the course of hardening off, never straighten up entirely, so that the side branches of shaded beeches have a graceful sweep, first rising gradually, then flattening out, then descending gradually, and finally turning upwards again.

As long as the leading shoot is strong and sound, and the light is not excessively reduced, it will go ahead with good erect annual increments, but temporary inclination from the vertical is usual.

(3) As a consequence of the afore-mentioned tendencies, the side branches of shaded beeches invariably make a wider angle with the main axis. The generally horizontal form of the branches causes the leaves to be more favourably disposed for making use of the reduced light, but whether shade is directly connected with the assumption of this habit, or whether this is a natural consequence of the relative weakness of the shoots, has not been ascertained. The wide occurrence of this trait was exemplified in some measurements of "mean

branch angle" of unshaded and shaded beeches on various sites. The branch angle measured was the angle A B X, X being a point on the branch 45 cm. (about 18 inches) from the origin, B being the point of origin and A being a point vertically above the origin: the wavy profile of many shaded branches made some such arbitrary definition convenient. The mean branch angle was taken as the mean angle subtended by the first five vigorous branches from the top down. Measurements on twenty trees at random provided an average for the stand: unshaded stands showed means ranging from 37 to 48 degrees: shaded stands showed means between 60 and 70 degrees.

(4) In very deep shade, the leaf size is reduced, and the tree suffers more or less from inanition. In moderate shade, however, the leaf size is conspicuously increased. This is a well known phenomenon with beech, and no detailed observations have been made on it. The assessment of the results of the experimental shading of nursery plants will include measurements of number, size and weight of the leaves in the different treatments.

(5) Observations in 1950, when (presumably because of the wet summer) late summer shoot extension in beech was unusually frequent, showed that shaded trees were less addicted than trees in the open. It is possible that this is connected with the competition for water and nutrients when beeches are growing under other trees, but it seems more likely that the result is due to the depressing action of shade on the root/shoot ratio. From several sources there is evidence that secondary extension is fostered when root development is vigorous in relation to shoot development: under canopy, shoot growth is promoted relatively to root growth. Under experimental shade, where the question of root competition did not arise, secondary extension was more frequent in the open than in the shaded plots. So called Lammas growth in beech takes two forms:—

(*a*) A secondary elongation, often of considerable length, at, or soon after, mid-summer, rather prone to insect injury, but usually ripening satisfactorily.

(*b*) A very short extension, probably in early autumn and apparently an anticipation of the resumption of growth in the spring. Such autumn shoots are commonly thick, fleshy and hairy: they, too, are subject to insect attack and they are often frosted.

It appears that both these tendencies are partly suppressed by much shade. Nevertheless, examples of both have been recorded on beeches growing in a relative light intensity of 30%, and it is clear that inherited tendencies, as well as shade and other environmental factors, are important in relation to late summer shoot extension.

Indirect Effects of Shade

(1) The blanket provided by a canopy maintains a more equable temperature, and thus reduces the risk of spring frost, which is often the cause of stunted growth and forking of young beeches.

(2) Less frequent secondary shoot extension under shade means less frequent damage by autumn frost, and by caterpillars which affect these tender growths in the late summer. A Tortricid caterpillar appears to be specially associated with the late summer shoots: its attentions weaken or kill the leading shoot and sometimes initiate forking.

(3) On the other hand, shaded beeches in the forest are more prone to attack by insects which breed and feed in the shelter trees. Birch, oak and other broad-leaf trees harbour numerous caterpillars, especially in spring and early summer: these drop on to the beech underwood, where they cause some defoliation and occasionally bite through the leading shoot. The caterpillars which have been noted on young shaded beeches in spring or early

summer include several Geometrids (*Operophthera brumata*, *Erannis defoliaria* and others) and Tortricids (*Peronea ferrugana*, *Cacoecia xylosteana* have been identified) as well as occasional representatives of other families. Weevils of the genus *Phyllobius* are also common, but probably confine their feeding to the foliage. Damage to shoots and buds from this source appears to be commoner under canopy, and the result on some sites is a rather frequent short die-back of the tip of the leading shoot severed by the larva. It appears to be unusual for this type of injury to result in a fork. If the severance is near the apex of the year's growth, as is commonly the case, the next lower bud resumes growth in the following year from an advanced position, whence it can usually outdistance possible rivals. In the rarer case of damage near the base of the shoot, the results may be more serious. On the other hand it seems that insect damage to secondary (Lammas) shoots commonly causes either such a weakening of the apical bud that it fails to hold its lead in the following year; or else it dies and is succeeded by several competitors, so that a fork ensues; or haply a new leading shoot arises from a strong side branch, making a marked kink with the original axis.

General Observations

(1) Somewhat earlier flushing and, perhaps, later leaf fall, give shaded beeches a slightly longer growing season. This helps to compensate for the shorter effective day in photosynthesis. On a dull June day, unshaded trees may, perhaps, find the light adequate for photosynthesis half an hour after sunrise, when the intensity is about 100 foot-candles (1075 lux), whereas another hour and a half may elapse before beeches receiving 20 per cent. of daylight enjoy this degree of illumination. There would then be a daily loss of three hours of photosynthesis as compared with unshaded trees. On bright days, however, the loss is somewhat greater, owing to the fact that, when the sun is low, the light rays must traverse the foliage of the overwood obliquely. Towards midday in summer the outside light is so great, even under an overcast sky (usually more than 1,000 foot-candles), that moderate shading can do no harm. Under deeper shade, however, the light intensity may be far below the optimum at all times, except when the sun is shining from a point well above the horizon. In these conditions, the light intensity in the open may be equivalent to 4,000 foot-candles or more, and a 95 per cent. shade may still transmit 200 foot-candles. The liminal and optimal light intensities for net photosynthesis in beech have not been worked out, and these figures are merely quoted to show the general effects which may be looked for. It may be concluded first that shade restricts photosynthesis by more or less curtailing the daily period when photosynthesis exceeds respiration, and secondly that, under deep shade, the amount of photosynthesis must be greatly influenced by the duration of sunshine.

(2) The influence of shade on leaf size is important in several ways. The larger, thinner leaves of shaded beeches, arranged at right angles to the incident light, are adapted to make the most use of low light intensities. When nursery plants are transplanted to a forest site under canopy, their initially small sun leaves are remarkable among the large shade leaves of long established beech transplants. Such plants doubtless experience a considerable handicap until they assume the shade habit. Similarly beeches which have grown for some years under canopy do not, when suddenly uncovered, at once assume the small sun leaves.

(3) The effects of shade are doubtless bound up with soil conditions and topography. It is known that for some plants tolerance of shade is greater where soil moisture and nutrients are abundant, than where they are in short supply. It may be supposed that with beech the minimum relative light intensity

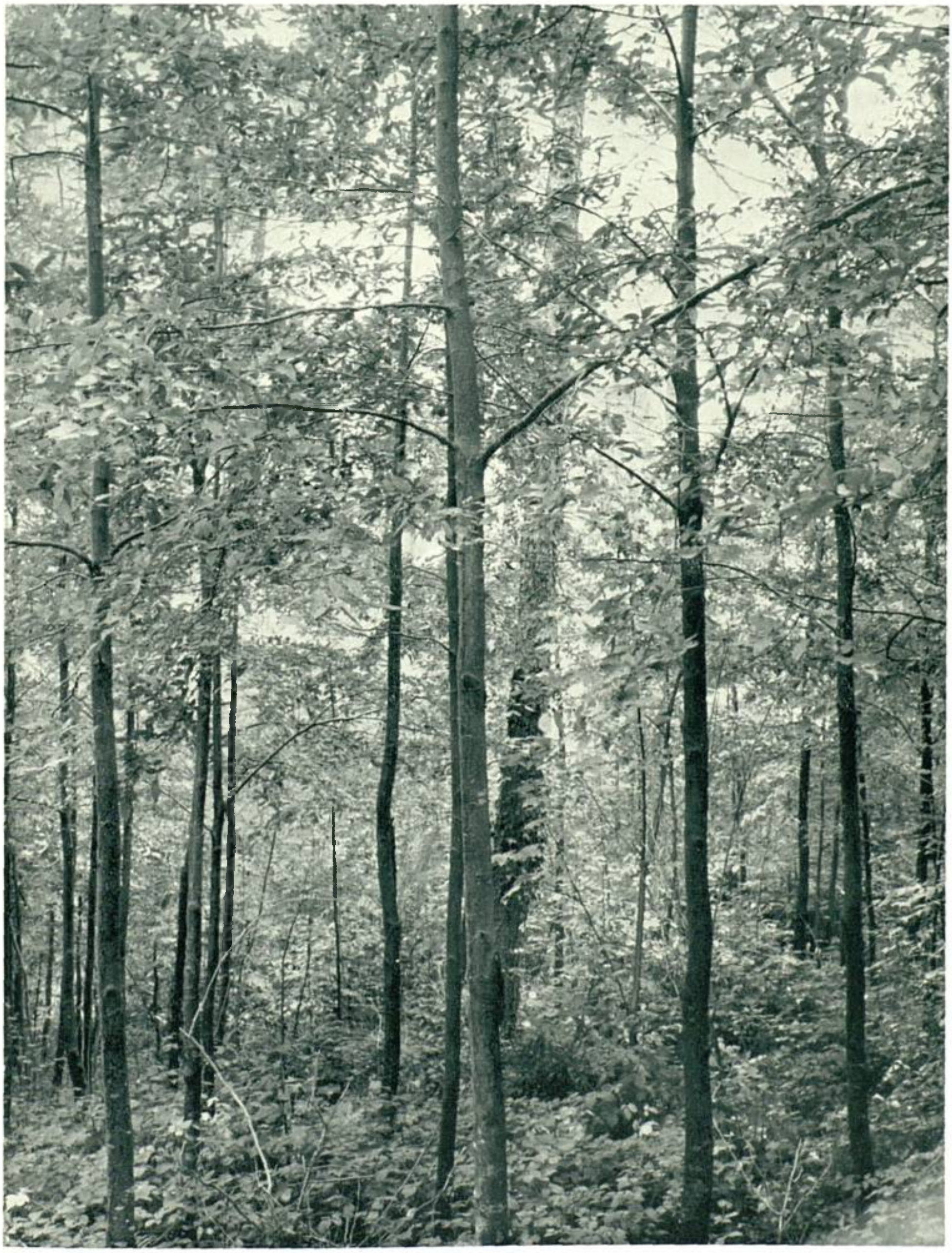

Plate I. Crop of *Nothofagus procera*, 21 years old, underplanted in a larch plantation 60 years old at time of planting. Note the excellent form and clean growth of the *Nothofagus*. Sample Plot E. 32. Haldon Forest, Devon. (See page 88.)

Plate II. A "plus" stand of beech — one of the finest in the country — in a privately owned wood. Age approximately 150 years, height 100 to 108 feet. Kingscote Wood, Nailsworth, Gloucestershire. (See pp. 67 to 77.)

Plate III. A "minus" stand of beech, typical of much of the growth on the Chiltern Hills. (See pp. 67 to 77.)

Plate IV. Oak and larch strip mixture with 6 rows of oak to 3 of larch, 19 years old, showing relative rate of growth of each species, Crumblands, Expt.4 (P.31) Tintern Forest, Monmouthshire. (See page 46.)

for vigorous height growth and erect leading shoot is higher on shallow dry infertile soils, where adequate root development is specially important. On such soils, too, the influence of shade on Lammas growth may be unimportant, because the soil conditions are such as to impose a general inhibition on secondary shoot elongation. Shading is bound up with the interception of wind and radiant heat. This is very important on exposed sites, and largely accounts for the frequent better growth of beeches under shelter. The lower temperatures and reduced air movement under canopy allow photosynthesis to proceed under conditions where unprotected beeches respond by closed stomata, or may suffer lethal injury.

(4) In the great majority of cases, forks and crooks can be traced to a definite, identifiable, accidental cause, which may be frost, insect or rodent injury, or mechanical damage. They do not arise spontaneously, but heredity is important in determining the phenological traits (time of flushing, late shoot extension) upon which liability to injury depends. Rarely twin or trident apical buds have been observed on individual beeches and it is possible that, independently of accidents, some trees are prone to produce two leading shoots. There is no reason to suppose, however, that such trees are an important source of the manifold forks seen in beech plantations. Because of this it seems unlikely that the flattened branching habit imposed on shaded beeches is any security against forking. Such influence as shade has is probably all exercised through the accidental proximate causes of forks.

(5) In some cases reduced height increment of unshaded, as compared with shaded, beeches may be in a large measure accounted for by forking; the nourishment which should properly go to a single leading shoot being spent among several rival shoots. This was noted in Eartham Wood in the 1950 growing season.

(6) Once forking begins, further troubles are made more likely, because the weakened leading shoots more easily surrender to any vicissitude. On the other hand strong, single, leading shoots can take minor mishaps (gnawing, severance of the tip, defoliation) in their stride.

(7) The problem now is to find a degree of shading for beech which is strong enough to stimulate height growth and suppress (or reduce) Lammas extension, but not strong enough to cause weakness, light hunger, or the "table-topped" habit. A convenient practical means of estimating the optimum degree of shading is also desirable. Present observations suggest an optimum lying between 20% and 35% relative light intensity, preferably given by a moderately dense, fairly uniform, crop of light trees (birch, ash, pine, etc.); but group planting in gaps amidst standing woods is also suitable.

CLIMATE AND SOIL IN RELATION TO BEECH GROWTH IN BRITAIN

By J. M. B. BROWN

Forest Ecologist

As a planted tree beech is found in all parts of Britain, but only sparingly in North Scotland and Western coastal districts. As a native tree, beech is probably restricted to the southern counties and mainly to calcareous soils, but in the most important tract of semi-natural beechwoods (the Chiltern Hills) the soils are mainly non-calcareous. In other districts, planted beech occurs on a wide range of soils, and it is of interest to compare the performance of beech on different soils in different parts of Britain, and specially to determine how far it is ecologically justified to regard beech as a tree of chalk and limestone. This was a principal object of the survey of mature beechwoods which was concluded in 1950. The extensive plantations of beech in Scottish policy woods and in parks in the North of England, which were established during the late eighteenth and early nineteenth century, afforded a comparison between height growth in the northern half of Britain and height growth of planted and natural beech in the forests of the Chilterns, Cotswolds and South Downs. In the course of this work a good deal of information was obtained about the relative influence of climate and soil.

The beechwoods recorded were broadly classified on the basis of soil into beechwoods on calcareous soils; beechwoods on non-calcareous loams; and beechwoods on sandy soils. As concerns the growth in height and diameter, there is little to choose between the best representatives of the three types. Heights of 110 feet at maturity (Danish Quality Class I) were recorded for beech on Cretaceous chalk and older limestones; on non-calcareous loams; and on sands and sandy loams varying in character and derivation. Three points are particularly worth noting:

(*a*) First quality class beech was recorded on somewhat podsolised sand as well as on sandy brown forest soils with mull.

(*b*) Relatively shallow rendziniform soils occasionally yielded first quality beech.

(*c*) First quality class beech was occasionally found in the north: heights of 100 feet or over were, however, rare in Scotland.

Protection from the prevalent westerly winds was one feature which all the first quality class beech stands had in common.

On very shallow rendzina soils, beech is rather short in stature, and small, particularly on south and west aspects, where the tree is also sensitive to summer drought, root disease and death being not infrequent. Beechwood on rendzina does not appear, however, to be a stable, or climax, association. Although many beechwoods were seen on rendzina soils, they were all, presumably, first crops planted on grassland. An exception is provided on steep scarp and valley slopes, where the immature chalky character of the soil is maintained by erosion, and a topographical climax developes. Elsewhere, on uplands and the easier slopes of spurs and ridges, the soil undergoes profound changes, parallel with the succession in nature from limestone grassland to beech forest. The main feature of these changes is the gradual leaching of the calcium carbonate. The soil "A" horizon becomes progressively deeper, while other important changes involving the retention of water, the structure, and the amount and distribution of organic matter, follow the removal of free calcium carbonate. In the course of time there develops a brown forest soil of satisfactory depth, such as was seen in some beechwoods of the Chilterns and South Downs. Very good growth is found on these brown forest soils over chalk, as well as on some of the transitional rendziniform soils. In the climax beechwood on brown forest soil, brambles (*Rubus*) tend to dominate the ground flora, and the calcicole herbs (of which *Sanicula europea* and *Mercurialis perennis* are the most constant) become less conspicuous.

Thus the climax beechwood association formed on calcareous parent rock closely resembles in most respects the beechwood on fertile non-calcareous loam, such as occurs on Chiltern clay-with-flint, on the loamy drift which overlies much of the downland chalk, and on fine-textured soils from other formations in various parts of the south and midlands. On sites somewhat sheltered from the prevailing winds, heights of 100 feet at maturity are usual, there is mull humus, and brambles are dominant in the ground flora of the older wood. In Scotland, however, brambles are absent, and a herbaceous flora is found in the beechwoods on fertile loam. Beechwoods on non-calcareous loam may occasion soil degradation under the influence of the westerly wind, or where the canopy is so dense that the breakdown of litter is arrested. In these circumstances mor is formed, the surface soil may become slightly leached, and the height growth tends to fall off. Owing to better retention of water, as compared with rendzina soils, the fall-off in height growth of exposed beechwoods is less marked on the deep loams. When, however, mor forms and leaching begins, the roots tend to become concentrated in the mor, and the soil is not fully exploited. Remarkably good height growth of beech was occasionally recorded on deep retentive non-calcareous loams on fully exposed sites at considerable altitude. In Westmorland, for example, a mean height of 85 feet was noted on a fully exposed upland at 1,100 feet: the soil was a rich retentive loam over mountain limestone.

The sandy soils examined embraced a wide range, from deep, base-rich, brown forest soils with mull to definite iron podsols. The height growth of beech also varied much on sandy soils, but there was no close correspondence with the character of the soil. Mean heights of well over 100 feet were recorded in the south on brown forest soils derived from Upper Greensand and Permian New Red Sandstone formations, and in the north on an alluvial brown forest soil with mull. On podsolised soils, with mor and a bleached "A" horizon, the best beech stands were not so good, but mean heights of 90 to 100 feet were frequent, and on one fully sheltered valley site a mean height of over 110 feet was noted. Sandy soils are much more readily leached and, under the deep shade of beech, the litter, somewhat resistant to attack by micro-organisms, tends to accumulate and form a thick mat of raw humus. Where the leaves are scattered by wind, the litter accumulation is less, but the acidification and leaching of the surface soil are usually accentuated. The ground flora on degraded beechwood soils is characterised by calcifuge mosses (*Dicranum scoparium*, *Dicranella heteromalla*, *Hypnum cupressiforme*, *Leucobryum glaucum*, *Mnium hornum* and *Polytrichum formosum* are the most widely occurring species) and the silver hairgrass, *Deschampsia flexuosa*. Blaeberry (*Vaccinium myrtillus*) is a frequent constituent in northern beechwoods.

The beechwoods seen on sandy soils were mostly, if not all, planted, and equilibrium between soil and vegetation doubtless did not exist. In these circumstances it is difficult to characterise the climax soil of the beechwood on sand—if it indeed exists; but it may be regarded as probably rather a degraded brown forest soil than a developed podsol. Much, however, depends on topography (particularly the exposure to the westerly winds) and on treatment (especially thinning). Regular thinnings, mainly by admitting the warming rays of the summer sun, promote the decomposition of the litter, stem the accumulation of mor and prevent leaching. There is reason to believe that the beechwood on sand is not a durable association, because the mor layer tends to preclude regeneration and it is doubtful if, even if free of rabbits, the wood can regenerate itself. It is, however, evident that beech of high quality and large size can be grown on acid sands of poor nutrient status, provided they are deep and adequately drained.

Comparatively little information has been obtained about the growth of beech on gleyed soils. The loams and clay-loams examined mostly showed satisfactory drainage; a gley horizon was, however, recorded in the profile of some silty glacial drift soils, where beech was observed to be growing satisfactorily, although height growth was not outstanding and the root system was somewhat restricted in depth. In a few cases local depressions showed the beech unhealthy or dead, and it was clear that a permanently high water table is very adverse. A more detailed comparison of the growth in height and diameter, and the distribution of roots, of oak and beech in gleyed soils is being undertaken.

Within the range of Britain it is clear from the observations made that climatic factors are more generally vital to the beechwood than edaphic factors. Waterlogged soils are manifestly unsuitable, but, within the range of other soils investigated, which included sands, loams and loamy clays, rendzinas, brown forest soils and podsols, beech will grow well and, on otherwise favourable sites, be of good quality. At the two extremes (shallow rendzina and sandy podsol), there is a fall-off in rate of growth as compared with the deeper chalky soils, acid loams and deep unleached sands. The effect of these soil differences is, however, generally overriden by climatic differences. As regards the beechwoods examined, the local climatic differences due to topography appeared to be more influential than the major climatic differences due to latitude and altitude. This is, however, partly because no stands were examined in the extreme north, in western coastal districts, nor at very high elevations. In these conditions beech would probably be of poor quality and rough form (though there are said to be a few good stands in sheltered positions in Sutherland and Argyll). At lower elevations in all parts, however, well marked differences in quality were noted between beechwoods on sheltered sites, and beechwoods on sites fully exposed to the west winds. On the drier soils the difference amounts to between one and two quality classes.

Climate is also of great importance in relation to the regeneration of beech. Low summer temperatures limit the production of flower buds, so that abundant flowering can nearly always be traced to a preceding warm sunny summer. Spring frosts not infrequently damage the flowers, and may further prolong the intervals between full masts, which are primarily determined by summer temperatures. In stands of similar age and canopy density, fruit production is freest on sunny slopes in the south: but abundant seed was produced by many Scottish stands in 1948 and 1950, following the exceptionally sunny summers of 1947 and 1949. As regards soil conditions, regeneration of beech is most successful on mull soils, where the leaf litter breaks down fully and without undue delay, so that there is no thick accumulation of matted leaves or mor. The best conditions are provided where burrowing animals make a spongy surface mull, and help to bury the nuts. The worst conditions are found on sites where the westerly winds sweep the floor, deprive the nuts of the concealment afforded by the leaves, and desiccate the germinating seedlings. In this environment, as also on thick layers of undecomposed litter, the beechwood fails to reproduce itself.

Relative Height Growth of Beech and other Trees

Many of the trees associated with beech appear to be considerably more sensitive to edaphic factors than is the beech itself. The species, therefore, which find a place in the mature canopy differ much from site to site. The relative height growth of beech and other indigenous and naturalised trees on different soils needs further investigation, but some provisional notes may be quoted.

On shallow rendzina soils ash regenerates very freely, but is fairly soon outgrown by beech, which commonly forms a pure crop, although in many places an understory of yews is a feature. It should be mentioned, however, that, on warm dry chalk slopes, beechwood fails to develop and the climax appears to be xerophile scrub, with scattered yews, whitebeams and oaks. Beechwood could be artificially established, albeit with difficulty, on these sites, but the results would be disappointing, and deaths would be frequent in periods of drought. On the deeper rendziniform forest soils, both beech and ash grow rather taller and more vigorously; an occasional ash may keep a place in the canopy, but beech is the natural dominant. Trees such as larch and the pines, which are often used to nurse beech on these soils, grow well at first and may threaten to suppress the slower-starting beech: but they are eventually outgrown and outlived by beech. Oak plays an important part in the succession from limestone grassland to beechwood, but has no place in the canopy of the climax beechwood. Lime (*Tilia europea*) has been noted in a few planted beechwoods on deep rendziniform soils, where its height growth was such as to suggest that it may compete on equal terms with beech.

On the sub-neutral loams, ash reaches its finest development and large trees equal, or hardly inferior, to the beech dominants are frequent in many beechwoods on these soils. Oak also grows much better, but not quite so tall as the beech and so only occasionally holds its place in the mature wood; dominant oaks in this type of beechwood are often very fine trees, but oak is more frequent in the sub-dominant and suppressed classes. Like ash, sycamore makes its finest growth on the sub-neutral loams, but the final height, although occasionally exceeding 100 feet, is inferior to that of beech or ash. The same holds for wych elm and for lime, which attains, however, a slightly greater height in the south. Larch grows very vigorously when young, and becomes a suitable nurse for the beech where such is needed. In young plantations ash and sycamore will outgrow beech, especially in the moister west. Under the light ash canopy many sub-dominant and suppressed beeches may survive and ultimately equal, or surpass, the ashes in height: under sycamore, however, this appears unlikely.

On more acid loams the performance of ash and sycamore declines, while oak and beech, although hardly as good as on the sub-neutral soils, grow very well and are more equally matched. Oak is a common constituent of the beechwood on acid loams, where it responds to the association with beech by growing taller, straighter and cleaner than in a pure oakwood. The more exacting leaf trees (ash, sycamore, elm, lime) are rarely found on these soils showing a pH of 5 or under.

Sandy soils of good base status are suitable for many species in addition to beech: oak, sweet chestnut, ash, wych elm and sycamore are occasional companions of beech. In virtue of its height, strong shade and longevity, beech is apt to dominate the older wood. On acid sands, oak (usually *Quercus sessiliflora*) and Scots pine are the only competitive species frequently seen, and beech is superior to either, although Scots pine may outgrow beech in early life. Some of the introduced conifers, especially Norway spruce and Douglas fir, are probably superior in height to beech on this type of soil, but no examples of such mixtures have been encountered.

It will thus be seen that, whereas the best development of beech is found on neutral, or slightly acid, brown forest soils, the strongest competitive power of beech is found on the markedly alkaline rendzina soils—although perhaps not on the extremely dry shallow rendzinas. Inasmuch as beech forest conduces to a gradual deepening and acidification of the surface soil, it appears probable that the pure beech forest of chalk and limestone soils is a temporary formation in Britain. By its action on the soil, the beech would, in the course of centuries, make the conditions more favourable to ash, oak and sycamore, which would then be found not only as groups of young regeneration, but as important constituents of the mature wood. The mixed beechwood here envisaged is typified by some planted and natural woods in the Chilterns and elsewhere, and may well have been widespread before human interference became a decisive factor in the succession.

CHEMICAL CONTROL OF WOODY WEED GROWTH

By G. D. HOLMES
Assistant Silviculturist

The preliminary experiments of 1949 on this subject were continued and extended in 1950. The chief object of the investigations was to develop treatments for the economic eradication of woody weed growth in the forest prior to planting. During the year under review work was concentrated on three problem species, namely heather (*Calluna vulgaris*), rhododendron (*Rhododendron ponticum*), and hazel (*Corylus avellana*).

Heather

Two experiments were carried out on vigorous *Calluna* growth on Wareham heath, Dorset, testing a wide range of chemicals applied in solution in spray form. July applications of 0.4 per cent. of butyl 2, 4- dichlorophenoxyacetate (2,4-D) in oil, at 80 gallons per acre, gave a complete kill of ling, and no signs of recovery were apparent one year after treatment. Similar concentrations of the sodium salt of 2,4-D in water, at up to 160 gallons of water per acre, gave similar results, with regrowth from surface roots appearing about four months after treatment. Ammonium sulphamate applied at 70 lb. per acre in 100 gallons of water gave a good kill.

The kill obtained with 2,4-D in oil was most satisfactory, and efforts are now being made to work out minimal dosage requirements.

Rhododendron

The growth substances 2,4-D and 2, 4, 5-T have proved ineffective against this species, even in the seedling stage. The most generally satisfactory treatf ment has been ammonium sulphamate at 250 lbs. per acre in 200 gallons o- water. This treatment gave a complete kill when sprayed on freshly cut stumps remaining after felling mature bushes. Application as a foliage spray to coppice shoots present on stumps two years after cutting also gave complete kill of the stump and root system.

Sodium chlorate or sodium arsenite caused a considerable setback of growth when applied to stumps of large bushes, but the effects were not fatal.

Hazel

Extensions of the trials on young coppice growth using 2,4-D or 2, 4, 5-T, reported last year, show little promise of these substances being lethal either alone or in combination. Young coppice shoots can be killed back completely by midsummer foliage spraying, but little or no damage is done to the stool. Evidence to date indicates that there is little difference in the sensitivity of the species to sprays applied at different dates during the growing season

EFFECT OF HIGH PRUNING ON BARK-PEELING COSTS IN DOUGLAS FIR

By J. W. L. ZEHETMAYR

Assistant Silviculturist

In 1939 an experiment was laid out at Bennan, Cairn Edward Forest, Kirkcudbrightshire, to investigate the costs of high pruning. This particular experiment was on a large scale, and half-acre plots were subjected to various intensities of pruning. Among the objects of the investigation were the actual costs of the operation, the effects of pruning treatments on growth and timber quality, and the effect on the costs of all subsequent operations. It is now possible to give the results for one particular operation, that of peeling the bark from the poles.

The Douglas fir, planted in 1925, were fourteen years old at the time the experiment was established. Six different brashing and pruning treatments were applied to twenty four plots. The only two with which the present report is concerned are:—

(1) Unpruned control.

(6) All trees pruned at intervals of four or more years up to and including the second live whorl. This second treatment was intended to provide material for peeling tests during the pole stage.

Thinning was a moderate low thinning (C-D grade), and after a cleaning in 1939 thinnings were made in 1945/6 and again in 1950. Pruning was undertaken in 1939, 1946 and 1950.

At the second thinning in 1950 a considerable number of pruned stems were cut out in treatment (6) and it became possible to put bark peeling to the test as follows:

(1) All thinnings from treatments (1) and (6) above were marked, separated after extraction, and cross cut at a top diameter of three inches. The poles from (1) had been snedded for their entire length, while those from (6) comprised a section pruned in 1939, and a section pruned in 1946, while only a small portion at the top had been recently snedded.

(2) Trees were picked from each plot which matched approximately for girth, length, straightness and general appearance. Three such matched pairs of trees were put together to form two samples, each of which was estimated to require approximately one hour's work to peel.

(3) Two girls skilled in bark peeling were timed for the actual work. Each girl peeled all six trees of one sample pair, the order in which they were taken, i.e. pruned or unpruned first, being determined by chance. The girls were asked to work steadily and in fact did not know as a rule which lots they were working on. In all eighteen pairs were so dealt with. Results are set out in Table 22.

TIME REQUIRED FOR PEELING UNPRUNED AND PRUNED POLES OF DOUGLAS FIR

Table 22

Treatment	No. of stems	Man hours* for pruning 1939 & 1945	Total length of poles	Total pruned length	Volume Hoppus feet	Mean time in hours for peeling samples of 3 trees	Total time for peeling	Total time pruning* and peeling
Unpruned	54	Nil	1,177 ft.	Nil	89.2	1.03	18.6 man/hrs.	18½ man/hrs.
Pruned	54	17½	1,189 ft.	946 ft.	89.1	0.98	17.6 man/hrs.	35 man/hrs.
					Difference	0.05 hrs.		
					Difference for significance at 5%:—	0.06 hrs.		

* Calculated as a proportion of the total pruning costs per plot.

These results show that there is clearly no saving in peeling commensurate with the expenditure involved in pruning, at least up to the stage represented here. It was in fact noted during the operations that the "knob" or swelling often formed during the occlusion of a pruning wound was as much if not more of an obstruction than a branch closely cut by an axe on the unpruned tree. The 1946 pruning wounds, which were often only partially occluded, were an additional source of obstruction.

This finding emphasises the fact that where high pruning is carried out great care must be taken to see that the highest possible proportion of trees selected are likely to reach the final timber quality crop. Time spent on high pruning trees which fail to reach the final crop is wasted. The most important point is the selection of the best trees at the correct number of trees per acre and at the right spacing. These points are being covered by a separate series of experiments.

FOREST GENETICS

By J. D. MATTHEWS

Forest Geneticist

The Progress of the General Programme of Improvement

Three principal methods are being used to improve the inherent quality of future plantations in Britain.

Method One—Improvement by mass selection

The location of suitable seed sources for current and future planting programmes continued during the year. Preliminary lists were prepared for beech, Douglas fir and Corsican pine in England, and these will be enlarged as the survey proceeds. Later lists will deal with the larches, Scots pine and oak in England. A complete survey of Scotland, covering all species in common use, is to commence during the autumn of 1951.

The woodlands visited are classified as follows:—

A or PLUS. Woodlands suitable for use as regular seed sources on an intensive scale. The standard set is high, and these stands will be reserved and treated to increase the production of seed.

B OR NORMAL. Woodlands suitable for use as seed sources, provided careful selection is made of the seed parents.

C OR MINUS. Woodlands unsuitable for seed collection purposes.

Method Two—Improvement by mother tree selection

We are fortunate in Britain in possessing a rich collection of specimen trees of historical and botanical interest. These occur singly or in small groups in arboreta, in the older private woodlands, and in State forests with a long history of management. Trees of this type are generally over eighty and often over 120 years of age, and if sufficiently outstanding are selected as PLUS trees for breeding and seed collection purposes. In years of good seed production, sufficient seed may be available from these specimen trees to make the formation of special plantations possible. If the performance of the progeny is above average, then these plantations will form useful seed sources in the future and could be treated as "seed plantations". A good example is afforded by the two early introductions of Douglas fir in the Lynedoch Wood, Scone, Perthshire. These trees were used as a regular seed source in the middle nineteenth century and many of their progeny are quite suitable as seed sources today.

Method Three—Improvement based upon the selection of both parents

The selection of a series of outstanding phenotypes (PLUS trees) continued during the year, concurrently with the survey of seed sources. Some of the selected individuals were successfully propagated by grafting and by the rooting of dormant cuttings during the spring of 1950. The propagation work was expanded during spring 1951, and grafts are now developing at two centres in England and three in Scotland.

The study of the techniques of tree breeding continued during the period under review, particular attention being given to the problems of grafting in the open nursery and in young plantations. Growth substances were used in the rooting of summer wood cuttings with some success, and the influence of the rooting media on speed of rooting was studied in a preliminary manner. The stimulation of early flowering and fruit production by root pruning, and by the use of selected root stocks, also received attention.

As in past years only very limited cross-pollination work was attempted, all energies being directed towards the selection and propagation of suitable material for use in the future.

Details of the progress during the year 1950 and 1951 are given by species, which are arranged in the same order as the two previous annual reports.

Corsican Pine

Study of Variation

Data collected during the survey of seed sources for Corsican pine indicates that the majority of the pure plantations established in State forests between 1920 and 1929 are of good inherent quality. The plantings of the year 1923 are an exception, being rather poor, but those stands formed during the years 1920, 1924, 1926 and 1927 are of outstanding quality. Over 600 acres of these plantations have been classified as A or Plus. In good seed years, and with treatment these stands could supply three quarters of our current annual requirements of seed.

A trial of methods of increasing the yield of cones in a twenty-year-old plantation has shown that girdling and strangulation of the stem can induce substantial increases in the production of cones two to three years after application. Crown size was also shown to be important; the bigger the crown development the larger is the cone production. It follows that regular rather heavy thinnings in specially reserved plantations, coupled with a restricted use of girdling and strangulation techniques, are of possible value in increasing home supplies of Corsican pine seed.

There are a few very good stands of Corsican pine over sixty years old, and half of the thirty Plus trees which have been selected for testing and subsequent inclusion in special seed orchards of Corsican pine come from these stands. The remainder of the Plus trees have been found in the A or Plus stands of the 21 to 30 age class. In the Midlands (Clipstone, Nottingham, and Cannock, Staffs., Forests) emphasis was placed on resistance to smoke damage when selecting Plus individuals.

An intensive nursery trial of progenies arising from free pollination was laid down at Alice Holt in the spring of 1950. The progeny of fifteen selected individuals are being compared with the plants obtained from six imported and from home-collected seed lots. The height growth of the one year seedlings was measured and tree 7/50, a Plus tree from Rendlesham Forest (Suffolk), gave a significantly greater mean height (2.21 inches) than tree 23/50 a Minus tree from Holkham (Norfolk) with a mean height of 1.40 inches. The remaining progenies formed a homogenous group between these two extremes, the overall mean height being 1.85 inches. This trial will be supplemented with new sowings from selected trees and bulk seed lots this year. The trees will be followed for three years in the nursery and twenty to twenty-five years in the field.

Corsican pine has been used principally on rather poor light soils in areas of low rainfall. The study of the possible extension of the range of this useful pine is being continued.

Propagation

The majority of the grafts remaining from the spring of 1950 consisted of those made under glass, very few of those made in the open nursery having survived. Outdoor grafting has sufficient advantages to make extension of this method essential. Experience gained this spring indicates that scions with a short group of needles clustered around the leading bud are the most suitable. The graft union should be at least two and one half inches long.

This year one hundred grafts were made from each of the selected trees. The scion material was grafted not more than four days after collection. The root-stocks used were transplants of Scots pine, *Pinus mugo* and Corsican pine, which had been one full year in their positions at the time of grafting. Scions of Corsican pine were grafted on to rootstocks of Corsican pine, Scots pine, *Pinus mugo* and lodgepole pine in spring 1950. The object was to induce early and persistent fruiting of the scion. These grafts are developing well this year.

A large experiment involving 4,200 cuttings (1,400 each of Corsican pine, Scots pine and *Pinus radiata*, taken from parent trees between fifteen and twenty years of age) was laid down in February 1950. The treatments consisted of, four different applications of growth substances, plus Sucrose and Vitamin B_1, repeated under seven different propagating conditions. The best result obtained was twenty-eight per cent. of the cuttings rooted for *Pinus radiata* under the most favourable conditions of closed case, high humidity and electrical heating of the media to 70°F. This batch of cuttings was also dipped in five per cent. Sucrose solution and ten parts per million Vitamin B_1, and then treated with 200 parts per million of indolyl-butyric acid, indolyl-acetic acid and naphthalene-acetic acid in talc. The treatments were almost completely negative for Corsican pine and Scots pine, only two cuttings of the latter species having rooted.

A nine-year-old hedge of *Pinus radiata* at Wareham Nursery (Dorset) was also used as a source of cuttings, using shoots which had arisen from fascicular buds after the customary clipping of the hedge. The short, sturdy cuttings rooted easily in a closed case with electrical bottom heating and without treatment with growth substances. Similar material from four-year-old plants of Scots and Corsican pines was next inserted with encouraging results. The method is now being tried on three twenty-five-year-old Corsican pine in Alice Holt Forest (Hants.). The trees have been disbudded, and the material which develops will be inserted later in the summer—probably late July.

Beech

Study of Variation

The majority of the best beech woodlands in England are to be found in the South Downs (230 acres of A or Plus woodlands) and the Cotswolds (seventy acres of A or Plus woodlands). The total acreage of Plus woodlands located in England amounts to less than 400 acres, but these will provide the nucleus of good material required to build up improved strains of beech. (See Photos 2 and 3 in central inset.)

The selection of Plus individuals of beech has been very rigorous, particular attention having been paid to persistence of the main axis and the quality of the utilizable stem. In general, Plus trees must have attained a total height of not less than ninety-three feet in eighty-six years (data from the Forestry Commission mean curve of mean height/age) and the stem must be suitable for veneer purposes.

Trials of grafts, and of progeny from free pollination, have been commenced. These are designed to show which of the selected individuals has high inherent quality, and the tested (Elite) trees will be put into one or more beech seed orchards and treated for high and regular yield of mast. Details of the first results obtained from the intensive nursery trials of beech provenances were given in the *Report on Forest Research* for 1950. An assessment of height (by inch classes) was made at the end of the second growing season. Four of the original provenances could not be included because of poor germination in the seedbed stage.

The order shown in Table 1 of last year's report was, in general, maintained. The one-plus-one transplants raised from seed collected from the two finest stands in England, namely Kingscote (Glos.) 12.33 inches, and Cirencester Park (Glos.) 12.02 inches, showed significantly greater height growth than transplants originating from seed from Benmore Forest (Argyll) 11.16 inches, or Edge End, Forest of Dean, 11.33 inches—both stands of Minus quality. This trial will be planted out in Alice Holt Forest during the winter of 1951/2.

A new trial of the progeny arising from free pollination was sown in late January 1951. This trial compares the progeny of forty selected Plus trees with those of nineteen continental origins from France, Germany, Belgium, Holland, Denmark, Czechoslovakia and Austria, and nine home origins varying from Plus through Normal to Minus. Assessments will be made along the same lines as in the earlier trial, with the addition of an annual assessment of the growth form of the seedlings. This type of assessment of form in early life has been already attempted in a preliminary manner.

Propagation

The grafts of beech made early in the spring of 1950 were not successful. It became obvious that the scion wood was not sturdy enough to withstand the premature development of the normal foliage buds which occured. Later that spring the Danish method was tried, with encouraging results, and the experience gained was used with good effect in Spring 1951. The method as used at Alice Holt is now briefly described.

The root stocks used are one-plus-two transplants, which are the thickness of a pencil at the base. The scion wood is obtained from the upper crowns of the selected trees. The scions are of three to four year-old wood, again the thickness of a pencil, and bear two or more healthy dormant buds. Normal foliage buds are not required, but one or two can be left on the scion if desired. The grafting method used is the whip and tongue graft, but the veneer side method is also possible.

This method has proved successful this season, both under glass and in the open nursery, and it is applicable to oak and possibly also birch. A further development, of possible use in the extension of the grafting season, is the grafting of sturdy scion wood taken when the trees have already flushed. If all the leaves are carefully removed, the dormant buds can again be relied on to develop, if the grafts are successful.

Some rising one-plus-one transplants of beech from Kingscote (Glos.) and elsewhere, and of European larch from Varel (North West Germany) were used as the subjects of a propagation experiment at Alice Holt. The effects of two factors on the rooting of summerwood cuttings were studied, namely the effects of time of taking the cuttings, and the effects of two methods of applying a growth substance.

One hundred and ninety two cuttings of beech were inserted each fortnight, commencing 19th June, 1950, and ending 31st July, 1950. The cuttings were treated with indolyl-butyric acid as a concentrated dip ($\frac{1}{2}$ mg. IBA per 1 cc. 50% alcohol) and by the dust method (6.25 p.p.m. and 50 p.p.m. in talc). The leaves were halved with a razor blade. The length of the cuttings averaged three inches.

The propagating conditions consisted of a closed case with electrical heating of the medium to 70°F. The rooting medium was coarse Bedford sand (75%) and peat (25%). Assessments of the number of cuttings rooted, and the number and length of roots per cutting, yielded the results now described.

The 19th June collection was the best (thirty eight per cent. of the cuttings rooted) followed closely by 3rd July (thirty one per cent.). There was then a sharp fall to five per cent. from the collection of 17th July, followed by a slight climb to nine per cent. from the cuttings inserted on 31st July. The optimum period thus appears to be the end of June. The concentrated dip method of applying the growth substance produced the best results, both morphological or stem roots and wound roots being produced. There was nothing to choose between the two dust treatments, which showed no significant improvement over the untreated controls.

The early cuttings had a further advantage in that they survived the winter of 1950 far more successfully than the two later collections. Further work on this problem of overwintering summerwood cuttings is in progress.

Observations made at Kew, Middleton Park (Oxford), and Thetford Chase (Norfolk), indicate that beech can be propagated by layering, provided the correct rooting conditions can be created. The production of standard rootstocks by this method for beech seed orchards is likely to be a practical proposition in the future.

European Larch

The Study of Variation

The survey of seed stands has so far been confined to a few scattered areas—principally North-east Scotland and the English Lake District. The work is now being extended to include the whole of Scotland.

Larch has proved relatively simple to propagate by grafting and forty outstanding or Plus trees have already been propagated. The testing of the value of these trees, particularly as regards susceptibility to the die-back of larch, will involve the laying out of extensive field trials of grafts and progeny in the areas of bad die-back.

Plus trees of Japanese larch have also been propagated with the object of raising improved strains of the hybrid larch. The first seed orchard of hybrid larch is to be established at Newton Nursery (Elgin) in the spring of 1952.

Propagation

Reference has already been made to the use of some rising one-plus-one transplants of larch from Varel in a propagation experiment. It was intended that the larch should be treated throughout in the same manner as the beech, but *Botrytis* attack intervened, and the only results available are for the 19th June collection.

One hundred and ninety-two cuttings were inserted on 20th June, 1950. Hormone treatments were identical with those for beech. Fifty-five per cent. of the cuttings inserted developed good wound roots, morphological or stem roots being completely absent. The concentrated dip method of growth substance application was again the most successful, but both dust treatments also produced substantial increases in the number of cuttings rooted when compared with the untreated controls (twenty six per cent. and twenty four per cent. of the cuttings rooted as against fifteen per cent. for the controls).

The propagation of the larches from cuttings continued to receive considerable attention throughout the year, the factors being studied including age of parent tree, type of cutting to be used and the influence of the rooting medium.

Scots Pine

Study of Variation

A number of parent trees for use in the future seed orchard were selected from the remnants of the old Caledonian Forest at Glentanar (Aberdeenshire), Loch Maree, Achnashellach (Wester Ross) and Glen Affric (Inverness-shire). One hundred grafts were made from each tree in the open nursery at Inchnacardoch (Inverness-shire). The study of Scots pine at other centres continues.

Propagation

Some success was obtained from the grafting of Scots pine in a heated barn cloche in December. Similar results were obtained in the previous year with Corsican pine, and the practice of grafting between October and December appears worthy of a follow-up. *Pinus mugo* has been used successfully as a rootstock for Scots pine, which result is in agreement with current Swedish experience.

Sitka Spruce

The Study of Variation

A general survey of Sitka spruce was made during the summer of 1950 with the following objects:—

To determine the variation in external morphology in this species.

To study the production of flowers and seed on a variety of site types.

To select a series of Plus trees possessing superior growth, vigour, and form, hardiness to late frosts and resistance to *Neomyzaphis* attack.

It has become evident on completion of the survey that although environmental factors are of the greatest importance in the development of high quality timber, vigour of growth, straightness and persistence of stem, angle, number and size of branching, width of crown, and times of flushing and flowering, are to a large extent genetically determined.

The older stands of Sitka spruce contain individuals with secondary branching, closely following the Comb, Ribbon, Brush and Plate types described for the Central European Norway spruce. It is possible also to distinguish five distinct cone types based upon the size, shape and margins of the cone scales and the overall size of the cones.

Isolated trees of Sitka spruce may commence bearing cones as early as twelve to thirteen years of age. Trees within a stand generally commence bearing from the twenty-fifth year. In exposed places flowering may occur at this age, but subsequent production of viable seed is much reduced. Flowering and fruiting is very dependent upon adequate crown development, dominant, perimeter and other isolated trees with well-developed crowns producing the heaviest crops. Trees on unfavourable sites bear earlier in life but not so heavily or regularly as trees on good sites. There is also a strong indication of a variation in the inherent capacity of trees to bear seed, excessive bearing often being correlated with poor vegetative vigour.

Forty Plus individuals were selected during the survey, and seed from most of them became available for sowing during the spring of 1951. The collection of the variants into one central place by means of grafting and the rooting of cuttings is also under way.

Propagation

The rooting of cuttings of Sitka spruce has been studied under similar conditions to those described previously for beech and larch and to those which are described subsequently for *Metasequoia*. The subjects for the experiment were four-year-old transplants in the nursery at Alice Holt. Three hundred and eighty-four cuttings were inserted on 20th June and 31st July, 1950. The cuttings were divided into two classes—large (up to six inches long) and small (up to four inches long) and were treated with indolyl-butyric acid as described for beech.

Both times of collection gave good results, the percentages of cuttings rooted being seventy-seven and eighty-four respectively. The smaller, less vigorous, more shaded, type of cutting rooted more easily than the longer, more vigorous and open grown type. The growth substances did not produce significant increases in the number of cuttings rooted, but indole-butyric acid applied as a concentrated dip in alcohol did increase the total length of roots per cutting. The rooting of cuttings offers a very convenient and valuable method of reproducing an outstanding individual for testing and perhaps for subsequent use in the forest.

Douglas Fir

A survey of Douglas fir was made during the autumn and early winter of 1950. The primary objects were firstly the study of the variation existing within the species and secondly the preparation of a preliminary register of seed stands and Plus trees in England. Assistance was given by Mr. K. F. Parkin, who had newly returned from a study of Douglas fir in Canada.

A wide variety of Douglas fir types, differing both in physiological and morphological characters, is to be found in our plantations. This is to be expected in view of the range of conditions under which Douglas fir thrives in its extensive natural habitat.

Stands of forty years and older are generally of a more uniform and superior quality than the younger plantations, the latter being characterised by an intimate mixture of types. Part of this difference in quality can be traced to a longer period of treatment of the older stands, but much can also be attributed to the seed.

The Plus trees selected generally possessed the following characteristics:—

outstanding vigour of growth; very erect smooth barked stems; short fairly light horizontal branches; foliage compact, needles fairly short and stiff; resistance to wind damage in the upper stem and crown.

The strain of Douglas fir mentioned earlier as being associated with the Scone Estate (Perth) possesses good growth vigour and good form of growth and appears to be worthy of further cultivation in Britain.

X Cupressocyparis leylandii

This interesting and possibly valuable conifer originated in 1888 as a chance hybrid between *Cupressus macrocarpa* Hartweg. and *Chamaecyparis nootkatensis* Spach. It was first noticed when Mr. C. J. Leyland collected seed from a specimen of *C. nootkatensis* at Leighton Hall, Welshpool. The early seedlings were planted at Haggerston Castle, Northumberland. Twenty-three years later, in 1911, two seedlings which represented the reciprocal cross were obtained at Welshpool when seed was taken from a tree of *C. macrocarpa.*

The hybrids have since grown well at Haggerston Castle and Leighton Hall. Rooted cuttings have also developed satisfactorily at Kew and the Bedgebury National Pinetum, Kent. The hybrid has been reported to be easy to propagate, and it has been the subject of six propagation experiments at Alice Holt (one on summerwood cuttings and five on dormant cuttings).

Our experience has been that *X Cupressocyparis leylandii* is only moderately easy to root, but that large scale propagation is a practical proposition. The best time to take summerwood cuttings appears to be July, or when the new wood has become sturdy, whichever is the earlier. For the quickest production of roots, dormant cuttings should be taken either October-November or March-April. The only time to avoid completely is when the material is newly flushed and in a tender condition. Dormant cuttings taken between November and the beginning of March will root, but they do not produce roots much before the others.

The best type of cutting (both summerwood and dormant) is four to six inches long and clean-cut just below the junction of the current and previous seasons growth. Leading shoots of side branches growing in partial shade are the most suitable. Material which is very woody at the base, or very weakly in growth, or bearing flower buds, should be avoided.

The age of the parent tree does not appear to be so important as the selection of the correct type of cutting. The oldest tree from which cuttings have been taken was twenty years old.

The best propagation conditions were a closed case with high humidity and electrical heating of the medium to 70°F. Cuttings were successfully rooted in 1949 in cold frames, with the aid of growth substances. No success was obtained in 1950, using standard commercial barn cloches. An experiment put down in the spring of 1950 in an unheated frame with double glass also gave poor results. Electrical heating of the medium appears to be essential for large scale propagation involving the rooting of several crops of cuttings each year.

Experiments to find what effects different rooting media may have, produced interesting results. One experiment (Experiment 5. P.48) showed that Vermiculite (an expanded mica) can give better results than coarse Bedford sand. This was confirmed by another experiment (No. 9, P.50) in which sand again gave poor results when compared with Vermiculite and a mixture of 90% sand and 10% peat. At present a medium containing 75% Bedford sand and 25% peat is being used in electrically heated frames, but further trials of mixed media are in progress. The pH of all the media used has been between six and seven.

Growth-promoting substances are of value in increasing the speed of rooting, and the number of cuttings with roots. They do not however make up for bad technique in other directions, and the optimum concentration for the production of a good type of root system (i.e. wound roots as against stem roots) is rather critical. Indolyl-butyric acid (500 p.p.m. in talc) has been used with success, and the concentrated dip method is to be tested this year.

Metasequoia glyptostroboides

The rooting of dormant cuttings of this species was reported last year. On the 17th June, 1950 three hundred and thirty six summerwood cuttings were inserted. A further one hundred and ninety two cuttings were inserted on 31st July, 1950. The cuttings were taken from two year seedling plants from Kew Gardens, and they were of two types—large and small. The small cuttings consisted of one deciduous shoot with a very short length of woody tissue at the base. The large cuttings were from three to four inches in length and bore several deciduous shoots.

The effects of applying indolyl-butric acid as a concentrated dip ($\frac{1}{2}$ mg. per 1 c.c. of 50% alcohol) or in two strengths in a talc carrier (6.25 p.p.m. and 50 p.p.m.) were also compared.

The propagating conditions consisted of a barn cloche with electrical bottom heating to 70°F. The medium was coarse Bedford sand (75%) and peat (25%). Assessments of number of cuttings rooted, and number and length of roots per cutting, were made forty and eighty-two days after insertion.

The effects of the growth substance applied as a concentrated dip were striking. When applied in this manner indolyl-butyric acid increased the speed of rooting, the number of cuttings rooted, and the total length of roots per cutting (seventy-three per cent. of cuttings rooted as against fourteen per cent. for the untreated controls). Both morphological and wound roots were produced by this concentrated dip treatment, the former appearing as masses of small roots on the stems of the cuttings. The stronger concentration of growth substance applied with a talc carrier had considerably smaller effects (thirty three per cent. of cuttings rooted) and the weaker concentration produced little improvement on the control.

The small cuttings rooted more readily than the large cuttings, but the rooted plants of the former type did not overwinter well and the initial advantage was thereby lost. More of the large cuttings taken on the 31st July rooted than the same type taken on the 17th June.

Miscellaneous Work

Contacts with Continental tree breeding stations were maintained during the year, and the continued assistance of workers in the field of tree breeding overseas is gratefully acknowledged. Mr. P. C. Nielsen of the Horsholm Arboretum, Denmark, spent two months with the section during Spring 1950

PERSISTENCE OF LATE-FLUSHING CHARACTERS IN NORWAY AND SITKA SPRUCE

By J. W. L. ZEHETMAYR
Assistant Silviculturist

The variation in flushing date in spruce is a well known phenomenon, and it has also been frequently observed that the relative date of flushing of individual trees is very constant from year to year.

An experiment was initiated in 1948 to discover whether this character was pronounced enough at an early age for trees to be selected in the nursery for use on special sites.

Accordingly in 1948-50 Research Foresters at various nurseries were asked to observe plants which had already stood one year in transplant lines, and to mark 200 early and 200 late flushing spruce. In all five lots of each species were marked, one or more at each of the following nurseries:—Newton, Benmore, Tulliallan, Fleet, Mabie and Harwood Dale.

At lifting, mainly as two-plus-two transplants, these plants were kept separate and taken to Newcastleton Forest, Roxburghshire. Here they were planted out in 1949-51 on a notorious frost shelf, in which several experiments planted in 1940 had been almost completely destroyed by a severe frost on April 26th, 1945.

Though so far there has been no spring frost severe enough to test the plants, the differences in flushing observed are so great as to be worth recording. In 1950 it was seen that the Norway spruce which had flushed early, in 1949, were fully flushed a fortnight before the late flushing specimens. This result has been repeated in 1951, late flushers being in the bud swelling stage when the early flushers had needles already an inch or more long. It is worth noting that the relative flushing dates remain consistent, in spite of the fact that the average flushing date in 1951 was almost one month later than in 1950.

With Sitka spruce, first planted in 1950, results in 1951 were not so striking as with Norway spruce but the differences were quite obvious.

Though the experiments are not yet completed—flushing dates have still to be observed accurately over the years and growth rate also has to be recorded —it does appear that any forester, by selection in the nursery transplant lines, could provide himself with a stock of late flushing Norway spruce for use in planting or beating up frosty hollows.

POPLARS AND POPLAR CULTIVATION

By T. R. PEACE, *Forest Pathologist*
and R. F. WOOD, *Silviculturist (South)*

The work which has been done during the year will be considered under detailed heads below.

Varietal Trials

England

Yardley, Northamptonshire	Large scale trial of most of the varieties in our possession prior to 1939, nearly completely planted.
Hockham, Norfolk	Small scale trial of a number of promising varieties started February, 1948.
Harling, Norfolk	Plots of a few selected varieties planted in a heavily cankered area; large scale trial of promising varieties started December, 1950.
Bagley Wood, Oxfordshire	Small-scale trial of a few varieties.
Gravetye, Sussex	Small-scale trial of a few varieties.
Bedgebury, Kent	Small-scale trial of a few varieties, a second small-scale trial planted December, 1950.
Orlestone, Kent	Small-scale trial of a few varieties.
Dartington Hall, Devon	Small-scale trial of a few varieties.

England (*continued*)	
Forest of Dean, Gloucestershire	Small-scale trial of a few varieties.
New Forest, Hampshire	Populetum, three trees of each variety, started December, 1948.
Quantock, Somerset	Large-scale trial of promising varieties started December, 1949.
Swanton, Norfolk	Comparative trial of four standard and a few other varieties.
Scotland	
Auchencastle, Dumfriesshire	Large-scale trial of promising varieties, started November, 1948.
Hallyburton, Angus	Large-scale trial of promising varieties, started December, 1948.
Brahan Castle, Ross-shire	Large-scale trial of promising varieties, started December, 1950.
Wales	
Dyfnant, Montgomeryshire	Large-scale trial of promising varieties, started March, 1948.
Clocaenog, Denbighshire	Small-scale trial of selected varieties at a high elevation, started December, 1949.

During the winter considerable additions were made to several of these trials. That at Quantock Forest, which lies in a sheltered, moist valley, gave very good growth; several of the others proved very disappointing.

Only two trials have proceeded far enough to give results. The larger one, at Yardley, is on heavy clay, on which establishment takes a very long time, so only the earlier planted plots have yielded any data. The smaller trial at Bagley Wood, Oxford, was planted later, but on a fertile valley soil, on which growth was rapid from the start; only a limited number of varieties were included. Even these have not gone far enough for any definite opinions to be based on them, though both show *P. robusta* as doing particularly well. The number of replications in each trial is very small, and no measurements will be published till results from a number of trials are available.

The collection contained 190 clones in November, 1950, and cuttings of a further 34 clones have been received since then. Some of these are only of botanical interest, and some have done so badly in the nursery that they will not be used in the trial plantations, but it is hoped to extend the trials to include all the more promising clones.

Silvicultural Experiments

Experimental plantations which have been made during the winter have been designed to give information on the following matters:

(*a*) *Age and type of plant.* This includes one-year plants from cuttings, two-year plants from cuttings stumped at the end of the first year, three-year plants from cuttings stumped at the end of the first year, and unrooted sets.

(*b*) *Method of Planting.* In all cases the plants have been put in well-dug holes; the difference in treatment lay in the presence or absence of a mound of soil round the stem, the main object of which is to suppress vegetation.

(*c*) *Mulching.* The two treatments are the presence or absence of a surface mulch to conserve moisture and reduce weed competition.

(*d*) *Manuring.* Two rates of application of a balanced N.P.K. fertiliser are being tried.

These four variables have been combined in a single experimental layout. In addition, the responses of two-year plants to N.P.K. are being investigated in a factorial experiment. These experiments are being carried out on four sites:

1. Alkaline river peat, previously arable.
2. Sand with a fairly high water table, but a heavy grass vegetation.
3. Rather wet coppice ground, recently felled, and having a heavy soil.
4. Stiff boulder clay with a heavy grass-herb vegetation.

No results are yet available.

Stocks are being raised so as to provide planting material for use in silvicultural experiments in future years.

Utilisation and Timber

No work on the utilisation of poplar has been carried out during the year, nor has it been possible to start any enquiries into shake or black heart. It is hoped to collect some data on these last two matters during 1951.

Certified Poplar Stocks

The scheme for supplying certified stocks of four poplar varieties to nurserymen, landowners and to Forestry Commission nurseries has now been in operation for three seasons. The numbers of cuttings supplied are shown below:

CUTTINGS OF FOUR KINDS OF POPLARS SUPPLIED FROM 1949 TO 1951

Table 23

	P. serotina			P. serotina, narrow crowned variety			P. gelrica			P. robusta		
	1949	1950	1951	1949	1950	1951	1949	1950	1951	1949	1950	1951
To State Forests....	200	1,356	1,735	150	1,356	1,610	200	876	1,610	250	1,356	705
To Estates and Nurserymen	900	2,017	3,820	1,705	1,417	3,275	1,506	2,427	2,310	2,224	2,542	4,655
TOTAL	1,100	3,373	5,555	1,855	2,773	4,885	1,706	3,303	3,920	2,474	3,898	5,360

It will be seen from this that the number supplied has increased steadily.

It is hoped that nurserymen will now soon be in a position to supply plants raised from these cuttings, for the main object has been to enable people to set up stool beds from which they can make their own cuttings.

In October, 1949, poplars were brought within the scope of the Importation of Forest Trees Order. Under this Order, licences are necessary before poplars can be imported, and in practice these licences are normally only granted for poplars of varieties known to be resistant to bacterial canker. For the more important varieties, such as the four named above, licences can only be procured if the imported stocks are certified true to name by a Government agency in the country of origin. This order has already been used to prevent the importation of several lots of undesirable varieties, which would probably have become cankered had they been planted in this country. It is tending, as it should, to restrict imports from abroad to those nurseries which are prepared to supply properly certified stocks, under definite botanical names.

Pathology

Results of inoculations with bacterial slime in 1950 were disappointing. Only on a very few trees did typical cankers develop. However, differences in the degree of healing between susceptible and resistant varieties were often appreciable, and a few natural cankers developed, probably as a result of infection from the cankered sets with which the trial plants are intimately mixed. The results so far clearly indicate susceptibility to bacterial canker in four clones, *P. trichocarpa* H.T., *P. Androscoggin*, *P. Northwest* A, and *P. tremula* x *tremuloides*.

Bacterial canker was found on *P. candicans* a few miles south of Inverness in Scotland, so that the disease now appears to extend over the whole of England, Scotland and Wales with the possible exception of North-west Scotland.

It was a bad year for *Melampsora* rust attacks, and data were collected on the degree of infection of all the clones in the collection. Owing to the observed variation from year to year in the incidence of these rusts on a single clone, and differences in degree of infection in different parts of the nursery, it is valueless to quote results for a single year. Data for varieties which have been under observation for a number of years have been summarized and will be published shortly.

Severe infection with *Dothichiza populea* occurred at Fen Row Nursery, Rendlesham, but only on two clones, Maine and O.P.19, both hybrids raised by Stout and Schreiner. *Cytospora chrysosperma* was also present, but it is considered that *Dothichiza* was the primary agent. In 1951 *Dothichiza* has proved very serious on newly planted stocks, especially on larger plants.

A *Phyllosticta* was found associated with minor damage to the leaves of *P. robusta* in one nursery, but it is not considered important.

Systematy

Mr. P. G. Beak, Deputy Director of the Commonwealth Forestry Bureau, has continued his studies, particularly of the *P. berolinensis* group, and he has provided invaluable help by his willing identification of poplar material.

P. serotina erecta in the strict sense (the De Selys poplar) has now been located at Kew, and at Colesbourne, where it was planted by Mr. H. W. Elwes, who described and illustrated it in his and Professor Henry's *Trees of Great Britain and Ireland*, Vol. VII.

Publications

Leaflet 27, *Poplar Planting*, published by H.M. Stationery Office on behalf of the Forestry Commission, has been revised and re-issued during the year. A much fuller publication, covering all the principal aspects of poplar cultivation on somewhat similar lines to the Dutch *Handbook voor de Populierenteelt* has been written and now awaits publication. A considerable bulk of observational data on bacterial canker and on *Melampsora* rust will be summarized in this publication, which will also contain a new key, prepared by Mr. P. G. Beak, for the identification of the principal species and hybrids cultivated in Great Britain.

A list of poplars in the possession of the Forestry Commission Research Branch was issued and circulated in November, 1950. As a result a considerable number of requests for cuttings have been received and they have been dispatched to Sweden, Italy, Germany, Switzerland, Canada, Argentine Republic, New Zealand and Southern Rhodesia, as well as to several persons in England interested in the behaviour of the newer hybrids. In addition, catkin material for breeding purposes has been sent to Holland, Belgium, and Austria.

International Poplar Congress

A great deal of time was spent in preparing for the Fourth International Poplar Congress which was held from April 25th-May 2nd, 1951. Fourteen countries were represented by forty delegates and experts. In addition, representatives from the Forestry Commission, Forestry Societies and Trade Federations in Great Britain were present. The Congress was on tour for eight days, during which time it visited the Forestry Commission Research Station at Alice Holt, Kew Gardens, the English Timber Supply Company at Danbury, near Chelmsford; the Forestry Commission Poplar Nursery at Rendlesham Forest; Ryston Hall, Downham, Norfolk; Ling Heath, Brandon; the Forestry Commission Forester Training School at Lynford Hall near Thetford; the poplar trial plots at Yardley Hastings Forest, Northamptonshire, the Imperial Forestry Institute; Kennington Nursery; Bagley Wood, Oxford; Messrs. Courtauld's Research Station at Maidenhead, and Eton College.

Two mornings in Oxford were devoted to meetings, which were held in the Imperial Forestry Institute. Most of the time at these meetings was devoted to the discussion of annual reports from member countries and other business, but short papers were given by Professor Houtzagers of Wageningen, Holland, on his tour of North America in 1950, in the course of which he visited many of the more important poplar regions; by Dr. von Wettstein of Austria, on the reaction of poplar varieties to the length of day; by Dr. Hilf of Hamburg, on poplar thinning; and by Dr. Heimburger on his work on poplar breeding in Ontario. The proceedings will be published in due course by the Food and Agriculture Organisation of the United Nations, who provide the Secretariat for the International Poplar Commission.

STUDIES OF GROWTH AND YIELD

By F. C. HUMMEL

Mensuration Officer

Sample Plots

The field parties of the Mensuration Section were, as in the past, mainly concerned with the establishment and remeasurement of permanent sample plots, but considerable effort was also devoted to the measurement of temporary sample plots in broadleaved species as a means of getting the information needed for preparing provisional yield tables. A summary of the establishment and remeasurement of permanent plots is given in Table 24.

ESTABLISHMENT AND REMEASUREMENT OF PERMANENT SAMPLE PLOTS

Table 24

	England	Scotland	Wales	Great Britain
Plots in being, 1st April, 1950	189	175	63	427
Plots established 1/4/50 to 31/3/51	16	18	—	34
Plots written off	2	1	—	3
Plots in being, 31/3/51	203	192	63	458
Plots remeasured 1/4/50—31/3/51	77	55	9	141

Of the sixteen plots established this year in England, eleven are coniferous and five are in broadleaved species. Apart from a single hybrid larch plot at Staindale in Yorkshire, all the new conifer plots are in the North West Conservancy, six at Thornthwaite in the Lake District and four at Kershope, Cumberland, areas where there had previously been no permanent sample plots. The species are Norway spruce, Sitka spruce, Douglas fir, Scots pine and Japanese larch. Of the five hardwood plots three form a thinning series in a 115-year-old beech wood at Nettlebed near Henley-on-Thames, Oxfordshire, the object being to find out whether thinnings can still appreciably influence the development of the crop at that age. The other two hardwood plots are in a 63-year-old stand of oak in Wyre Forest, Worcestershire, which was visited by the British Association last year, and in a 30-year-old stand of sycamore at Staindale in Yorkshire.

Of the eighteen new plots in Scotland, eight are at Drummond Hill Forest, Perthshire, in old silvicultural experiments comparing the rate of growth of Japanese larch, Hybrid larch and several European larch provenances. A thinning series of four plots, was laid out in a particularly fast-growing stand o Scots pine at Fochabers in Banffshire, while the other new plots are a hybrid larch plot at Strathord, Perthshire, a Sitka spruce plot at Bennan, Cairn Edward Forest, Kirkcudbrightshire, and a *Picea omorika* plot in the Forest of Deer, Aberdeenshire.

Among the 141 plots that were remeasured during the year, those with the longest history as sample plots provided the most useful information. This applies particularly to the Bowmont Norway spruce plots in Roxburgh, which were established in 1930 and are a striking demonstration of the effect of contrasting thinning treatments over a number of years. Height growth has continued to be substantially the same in all plots, but diameters are much greater in the more heavily thinned ones. In contrast to comparative thinning experiments elsewhere, in which volume increment has been similar in all thinning grades, the heavily thinned D grade and L/C plots have produced a greater total increment than the more lightly thinned B and C grade plots. If the correct explanation for this unusual behaviour can be found, it may throw some new light on the silvicultural requirements of Norway spruce in Britain.

Among the plots remeasured in England, the conversions of coppice with standards to high forest at Tintern, Monmouth, and at Dymock, Glos., and the underplantings of European larch at Dymock and Haldon, Devon, deserve special mention. The former suggest that it is best to remove the standards at a very early stage of conversion, while the latter plots are a good illustration of how European larch can be underplanted successfully with a variety of other species, both coniferous and broadleaved, including that uncommon but attractive South American beech *Nothofagus procera*. (Plate I, in central inset.) Success seems to depend very largely on the timely and drastic thinning of the larch over-crop. This undoubtedly leads to a reduction in the volume increment of the larch, but under favourable conditions the additional yield to be derived from the underplanted species may ultimately more than compensate for this loss.

The greater number of visits, compared with previous years, that have been paid to our sample plots by foresters and others, reflects the increasing importance that is being attached to the practice and theory of thinning in this country, and the value of sample plots as practical demonstrations of the effect of thinnings on the development of forest crops.

The three plots abandoned during the year were a Douglas fir plot at Stourton in Wiltshire, a Sitka spruce plot at Moorburnhead in Dumfries-shire, both owing to wind, and a Weymouth pine plot at Alice Holt in which the majority of trees had succumbed to blister rust.

A summary of the 334 temporary hardwood plots, by species and Conservancies, which were measured during the year is given in Table 25.

TEMPORARY SAMPLE PLOTS OF HARDWOODS MEASURED IN 1950 TO 1951

Table 25

Conservancy	Total	Oak	Beech	Ash	* Other Hardwoods
South-east England	63	18	39	1	5
South-west England	92	48	19	14	11
East England	105	40	31	16	18
North-west-England	54	28	5	3	18
North-east England	18	8	6	1	3
South Wales	2	2	—	—	—
TOTAL	334	144	100	35	55

* Other hardwoods include: Red oak, Norway maple, Spanish chestnut, wych elm, English elm, birch, sycamore, Turkey oak, and Black Italian poplar.

The plots are nearly all in fully-stocked stands covering the range of sites on which broadleaved species are usually found, but with special emphasis on stands of rapid growth and good stem form. These are considered a more reliable starting point for studies of yield than an ill-defined average, and it is on the best sites that hardwoods will most likely continue to be grown in the future. In addition, these very good stands may be of interest for future genetical work.

Most of the temporary plots measured were on private estates, and it is a pleasant duty to record the generous co-operation of the landowners and estate agents concerned, who not only allowed the measurements to be taken but often took considerable trouble in tracing and supplying details of the past history of the crops.

The field work for England is nearly completed, that for Scotland and Wales remains to be done. The results that have been analysed to date, in many respects confirm the findings of Trentham Maw, whose yield tables, published in 1912, deserve to be rescued from the oblivion into which they have fallen.

Investigations affecting Forest Policy

The practical value of studies of growth and yield lies mainly in the sphere of forest management and, on a national scale, in that of forest policy. During the year under review much time was spent on the practical application of existing knowledge to problems of forest policy, and while this has retarded progress on some of the research projects, it has ensured that good use is being made of past research. The main task was to prepare estimates indicating the probable short-term and long-term effects of several felling regimes, on the growing stock, increment and yield of the woodlands of Great Britain. They were prepared by applying to the facts revealed by the Census of Woodlands, the information on growth and yield provided by the permanent sample plot records and various investigations carried out during the past few years; and by supplementing this information where necessary by some clearly-defined assumptions.

Statistical Analyses

The main tasks were the analysis of the data from the hedgerow census, the compilation of the conifer volume tables, and the design and analysis of nursery and other experiments. Apart from the usual tests of fertilisers and other factors affecting early growth, which are dealt with by the analysis of variance, or sometimes co-variance, there were for the first time some weedkiller experiments, involving the use of probit analysis. Another new departure was the seed testing experiments in which the data sometimes have distributions other than the normal, and must therefore be transformed before analysis. In close co-operation with the Silviculturists, a considerable amount of effort was devoted to improving sampling techniques for the assessment of forest and nursery experiments, with a view to reducing the field work without sacrifice of essential information. The standing instructions on assessments which have recently been issued to Research Foresters are an outcome of this work. On the computational side, the possibilities of making more use than in the past of short cut methods were explored. The standard deviation/range ratio has proved to be particularly valuable as a quick and simple means of estimating standard deviations in the field; its use deserves to be more widely known among foresters, and a note on it has been accepted for publication in *Forestry*. The application to forestry of some of the other techniques referred to above is also, as far as is known, not widely practised, although the methods are well known in other fields of research. A start has therefore been made on preparing a comprehensive account of the use that is being made of these methods by the Research Branch.

Other Work

Owing to the unexpected volume of special studies, and the expansion of the statistical activities, it was not possible to carry out the entire research programme for the year, but progress has been made on the majority of projects. The general volume tables for Scots pine, European larch, Norway spruce and Corsican pine were completed for publication, and so was the table for Sitka spruce which was subsequently found to be redundant, as it was discovered that the Norway spruce volume table fitted the available Sitka spruce data equally well. This does not mean that there is no difference in form between these two species, but merely that there are insufficient Sitka spruce data to give an answer to this point. The volume tables for Japanese larch and Douglas fir remain to be done.

The revision of the yield tables for the conifers has been continued and new "top-height over age" graphs, by quality classes, have been completed for Scots pine, Corsican pine, Douglas fir, Norway spruce and European larch, those for Sitka spruce and Japanese larch having been drawn previously. The trends of these curves are similar to those published in the existing *Forestry Commission Yield Tables*,* but in both Scots and Corsican pine there were sufficient data to support a curve for a quality class above the existing first quality. The revised thinning schedules which were prepared for the new editions of Forestry Commission Bulletin 14, *Forestry Practice*†, and the booklet entitled *The Thinning of Plantations*††, are at the same time a step towards the completion of new yield tables. Based on recent experience and current Forestry Commission practice, the thinnings given in the new schedules start earlier and are heavier than in the old schedules.

The enumeration of a 500-acre block of Monaughty Forest in Morayshire may be regarded as a first excursion into the almost virgin field of management research. It was found that a reasonably satisfactory estimate of volume and increment could be obtained by having one-tenth acre circular plots spaced systematically at intervals of 220 yards throughout the plantation, giving a sampling fraction of 1%. Two men can cover approximately 1,000 acres in a fortnight in this type of survey.

A similar but more detailed enumeration, under entirely different conditions, and with the additional object of determining the probable sampling

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* H.M.S.O. 6d. † H.M.S.O. 2s. 6d. †† H.M.S.O. 1s. 3d.

errors in different forest types, has now been started at Alice Holt Forest, Hampshire, which comprises some 2,300 acres, is situated conveniently near to the Research Station, and contains a great diversity of stands for a forest of its size. The more ambitious project of selecting and managing a suitable piece of woodland according to the periodic inventory method (Méthode du Controle) has not been realised, but remains on the programme for next year.

Sixty six technical enquiries were received and dealt with during the year as compared with 27 during the previous year. Of these 18 originated from within the Forestry Commission, 28 from woodland owners, timber merchants, universities and other sources in Great Britain, and 20 from abroad. The majority of enquiries referred to mensurational instruments, sample plot methods, questions of sampling, and to points arising from articles published by members of the Section.

CENSUS OF WOODLANDS

By G. M. L. LOCKE

Census Officer

Census of Hedgerows, Small Woods and Unproductive Woods over Five Acres

At the completion of the main census* there were three tasks which remained. The first was to find the volume in hedgerow and park trees and narrow shelter-belts, the second was to find the volume, and distribution by type, in the woods of one to five acres in extent, and the third was to obtain the volume in the "Unproductive" woodlands which were not sampled in the volume survey of the Census of Woodlands. All three surveys were based on the maps used for the Hedgerow Census, and the various field investigations were done concurrently.

Hedgerows

This survey was carried out on a sampling basis. The method adopted, (which resembles one used in 1942) was to have three independent 1% samples of six-inch Ordnance Survey maps, designated the A, B and C schemes, so that the precision of the results could be estimated.

Taking the map based on Land's End as map 1, three random numbers between one and a hundred were selected. These three maps formed the base of the A, B and C samples, and each scheme was built up by taking the hundredth map thereafter in each sample.

The sampling unit was then placed on each map. This was a strip, two chains wide and one mile long, running from South to North from a point placed one inch above the southern boundary of the map. The reason for this was to make the starting point of the strip more easily identifiable than would have been the case if the strips had started on the edge of the map. On the strip any woods which had been surveyed in the Census of Woodlands, 1947-49, and any woods less than five acres but greater than one acre, were marked off, and were excluded from the survey. Thus on the strip only isolated trees or trees occurring in woods of under one acre or less than one chain in width were measured.

As all the final results of the Census were based on the land plus inland water area of each country, it did not matter whether the strip fell across a river or

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* *See*: Forest Record No. 3. *Census of Woodlands*, 1947-1949. *Summary Report*. H.M.S.O. 9d.

lake, provided it was not tidal, and no reduction in the area of the strip was made. Where, however, the strip fell across an area of tidal water, or fell on the sea, the strip was transferred either to another area of the same map, or to the adjoining map, whichever was the more suitable. In all 441 strips were measured, of which 252 were in England, 47 in Wales and 142 in Scotland. This gave a sampling density of 0.01%.

All trees which occurred on the strip and were capable of producing timber were recorded on the field forms. Four main categories were recognized.

(*a*) Timber trees of 6 inches breast height quarter girth and over and having a minimum length of 10 feet of sound timber. Three girth classes were differentiated:—

(i) 6 inches to 9¾ inches, (breast-height, quarter girth)
(ii) 10 ,, ,, 14¾ ,, ,, ,, ,,
(iii) 15 ,, and over, ,, ,, ,,

(*b*) "Shorts." Trees of 6 inches breast-height quarter girth, and having a length of 6 to 10 feet of sound timber.

(*c*) Saplings. Well grown trees 3 to 6 inches breast-height quarter girth, with a minimum length of straight stem of 10 feet.

(*d*) "Firewood Trees." Crooked, short boled or defective trees of all girths above 3 inches breast-height quarter girth having less than 6 feet length of timber or, in the case of saplings 6 ft. length of straight stem, or trees with a timber length of more than 6 ft. but containing serious defects in the bole.

All trees were recorded on the form by species and girth class, as they were encountered, and their height determined. Total height was measured in conifers and the height to 6 inches quarter-girth, over-bark, or to the spring of the crown, which ever occurred first, in hardwoods. Results are set out in Table 26.

VOLUME OF HEDGEROW TIMBER BY COUNTRIES

Table 26

Country	Volume in millions of hoppus feet over-bark (Timber only)			Percentage of Total
	Coniferous	Broadleaved	Total	
England	44.2	636.3	680.5	84%
Wales	10.8	75.7	86.5	11%
Scotland	3.6	36.1	39.7	5%
Great Britain....	58.6	748.1	806.7	100%

This table shows that 84% of the total volume is to be found in England, 11% in Wales, and only 5% in Scotland. Out of the total of 806.7 million hoppus feet, 748 million, or 92% is of broadleaved species.

One to five acre woods

The survey of the 1 to 5 acre woods presented a slightly easier problem, since we knew from a 2% sample carried out during the main census of woodlands, that the area of these woods was approximately 187,000 acres.

All the woods of 1 to 5 acres on one quarter of each map sampled for the Hedgerow Census were visited, and the information coded in the same manner as for the main census. The 187,000 acres were then split up and allocated to each type and age class, in the proportion in which the woods were found on the ground.

Almost 9,000 acres of these woods have been disafforested, and lost to forestry. Of the remaining 178,000 acres, 27,000 acres are Coniferous and 92,000 acres are Broadleaved, while 59,000 are classed as "Unproductive", which in this context includes Coppice-with-Standards, Simple Coppice, Scrub, and Devastated and Felled areas.

The volume of timber occurring in these small woods was obtained by applying, in the case of High Forest Types and Standards in Coppice, the average volumes per acre for each type and age-class found in the main census, to the estimated area figures for small woods obtained in the hedgerow census. Similiarly in the Unproductive "1 to 5 acre" woods, the volumes of each type were estimated by applying the volume per acre figures obtained for the Census Unproductive woods (i.e., Simple Coppice, Scrub, and Devastated and Felled Areas) to the area of each of these types in the small woods. Results are shown in Table 27.

ESTIMATED TIMBER VOLUMES IN SMALL WOODS

Table 27 Millions of Hoppus Feet over Bark

Country	High Forest and Coppice-with-Standards		Unproductive Small Woods	Total
	Coniferous	Broadleaved		
England	31	92	4	127
Wales	7	30	—	37
Scotland	16	42	1	59
Great Britain	54	164	5	223

These figures show that the standing volume in High Forest and Coppice-with-Standards in small woods in 218 million hoppus feet, or 9.5% of the standing volume in these types in Private Woodlands of over 5 acres. The balance of 5 million hoppus feet is in unproductive small woods.

Unproductive Woods over Five Acres

The volume in the "Unproductive" Census woodlands was obtained by measuring one acre sample plots in representative Scrub, Devastated, Felled and Simple Coppice areas occurring on maps sampled in the hedgerow census. From these results, average volume per acre figures were obtained for each of the four types, and these figures, when applied to the unproductive woodland areas, gave an estimated total volume of 85.6 million hoppus feet. The results of the main Census of Woodlands and this Hedgerow Census are summarised for Great Britain in Table 28.

VOLUME OF TIMBER CLASSIFIED BY SIZE AND CHARACTER OF WOODLANDS

Private Woodlands and State Forests combined

Table 28 Millions of Hoppus Feet over Bark

Category	Coniferous	Broadleaved	Total	%
Productive Woods over 5 acres	1,143.9	1,514.5	2,658.4	71
Productive Woods under 5 acres....	54.0	164.0	218.0	6
Unproductive Woods over 5 acres....	14.5	71.1	85.6	2
Unproductive Woods under 5 acres	1.0	4.0	5.0	—
Hedgerow and Woods under one acre	58.6	748.1	806.7	21
TOTAL	1,272.0	2,501.7	3,773.7	100

Census Maintenance

The Census of Woodlands has provided a clear picture of the present area and condition of British woodlands, but fellings and plantings continually change the position, and it is important that this information should be kept up to date as far as possible. At first it was intended to achieve this by altering the records for each stand whenever a felling or planting took place. This proved to be quite unworkable, and instead a much simpler annual record of plantings and fellings by counties, was decided upon, which is now being tested in one conservancy. These records will require to be supported by periodical field checks and suitable methods for conducting these are being explored.

Enquiries

Twenty-eight written enquiries have been dealt with, of which thirteen were from private sources and fifteen from within the Forestry Commission. Both the scope and the nature of the enquiries varied greatly, but the majority were concerned with the occurrence or prevalence of certain species or types of woodland in a particular locality. Seventeen County Councils have been supplied with small-scale photographs of the six-inch Census Maps to assist the County Planning Officers in dealing with Tree Preservation Orders. One University was also supplied with prints for an Ecological Survey of a National Park.

TREE DISEASES IN GREAT BRITAIN, 1950-51
A GENERAL REVIEW

By T. R. PEACE
Forest Pathologist

It is surprisingly difficult to make a general review of the status and effect of the diseases attacking trees in Great Britain. This is due to a number of factors. Firstly, our information on many of the diseases is very incomplete, often the cause is unknown, and frequently the disease has not been under observation long enough for any evaluation of its future potentialities to have been made. Naturally if the cause is not known, it is impossible to get any information from the behaviour of the same or a similar pathogen in another country. Secondly, even where we have more knowledge, we lack the staff to make the surveys and collect the data that would be necessary if we were to evaluate the degree of attack and the amount of damage done. Thirdly, many diseases in this country are tied up with climatic and edaphic factors, which may well alter in the course of time. In fact, some diseases are solely due to non-organic agencies. With such diseases the future course of events can only be anticipated to the extent that we can prophecy the future behaviour of the climate or the soil. Thus it is only possible to make very general statements about the disease position as a whole.

Generally, at the moment, the most serious diseases appear to be those of pole-stage crops. There are various reasons for the present emphasis on diseases of this age-class. Many of the earlier Forestry Commission plantings have now reached this stage, so that there is a bigger acreage concerned than was the case a few years ago. In the pole stage it is no longer possible to replace losses in the crop directly, and gaps made by diseases are permanent, except insofar as they can be filled with a shade-bearing species. On some soils, gaps in the canopy caused by disease may lead to much greater losses by windblow, and very often trees, afflicted by root disease, may blow over while the degree of attack is still relatively slight. Three diseases of this type, which must inevitably cause concern, are *Fomes annosus*, so far restricted as a killing agent to pines on the sands in East Anglia; the group dying of Sitka spruce and other conifers, attributed by Day to exhaustion of soils, on which, for various reasons, mainly impeded drainage, root growth is restricted, and the top dying of Norway spruce. The first of these has been extensively studied by Rishbeth, and as a result of his experiments one practical recommendation can be made. Treating the stumps of thinnings, which form sources of infection for the surrounding trees, with a mixture of tar and creosote, prevents them becoming infected with *Fomes* and appears economically worth while.

But as regards the other two diseases mentioned above, there is as yet no certainty of the causes, and we are far from being able to suggest remedies. It is quite certain that we are dealing with two different diseases, for the group dying of Sitka spruce starts in the roots, indeed the whole root system may be dead before the crown has succumbed; whereas the top dying of Norway spruce starts in the crown, and most of the roots, and the base of the main stem, are still alive when the top is dead. In neither case, so far, has any fungus been found to be generally present; though in both cases the general symptoms and the method of development of the disease would be quite typical of attack by a fungal pathogen. The Norway spruce disease is certainly not entirely attributable to soil conditions. Though some of the soils where the Sitka spruce disease occurs are certainly desperately shallow, or rendered shallow by the behaviour of the water table in wet seasons, other sites have soils that would appear to be capable of supporting healthy, even if not particularly rapid, growth to a greater age than thirty years. In addition the method of spread of this disease in extending groups, the dying of certain roots completely, before others show any real sign of attack, and the failure of temporarily surviving trees to benefit from the extra root space provided by the death of those around them, all point to a less simple explanation than exhaustion of the soil available for free rooting. So far work on these two diseases is really only in the observational stage, but experiments, designed to throw more light on the relationship of the trees with their site, have been planned, and in some instances put into operation. Thinning, drainage, trenching around infected areas, and manuring are all under consideration. The possibility of fungus infection is naturally also being investigated, and experiments to test the possibility of virus infection have been started. It is hoped that early results with some of these may narrow the present wide field of investigation.

The debility of Corsican pine on a number of sites in the north of England and Scotland is on a slightly different basis, for some of the crops attacked are not yet in canopy, though others are in the pole stage. This trouble has been variously attributed to the fungus *Brunchorstia destruens*, and to autumn frost. All that can be said so far, is that *Brunchorstia* does not appear to be generally present, though it does occur, and that many of the sites, where the disease occurs, are in positions where unseasonable damaging frost would appear to be highly unlikely. The disease has often been associated with pine planted at high elevations in districts with high rainfall. In fact, though none of the affected areas are in districts which would now be considered obviously suitable for Corsican pine, some of them are in reasonably dry climates, and not particularly high above sea level.

Several more cases have come to notice during the year of the dying of Scots pine on highly calcareous soils, and in one instance Corsican pine was also seriously affected. It appears certain that there are a number of soils on which Scots pine, and possible Corsican pine as well, can only be used as nurse crops, and on which there is no certainty that they will even reach the pole stage, though they may well do so. Such soils are usually dry as well as calcareous, and it is doubtful whether any other conifers would grow on them at all. On old woodland of this type, beech can probably be established without nurses, but on chalk grassland, on present evidence, Corsican pine is a safer nurse than Scots pine, and can be expected with reasonable confidence to reach utilizable age before calcareous deterioration affects it. The course of deterioration of pine on these soils would be well worth detailed study, and might well throw some light on the behaviour of conifers on shallow soils, discussed above.

It is curious that, though we have several serious diseases in pole crops affecting, at a comparatively early stage, the health of the whole tree, we have relatively few canker diseases, particularly as compared with America. So far little damage appears to have followed brashing or pruning, though subsequent injury, attributed variously to fungi and frost, has followed these operations on a few occasions. Van Vloten appears to have definite experimental evidence that infection by *Phomopsis pseudotsugae* can follow winter brashing on Japanese larch. Very similar cankers have been found in this country, and though they were not discovered till all evidence of fungal invasion had disappeared, it seems quite likely that the cause is the same. Fortunately their occurrence has so far been restricted to a few limited areas.

Day has now firmly established the relationship between larch canker, frost and provenance. But he has perhaps neglected the possible role of the fungus *Dasyscypha* in this complex. During the year Dr. Manners of the Botany Department at Southampton has done successful wound inoculations with *Dasyscypha* on larch growing near Penzance, an area definitely free from damaging frosts. It is thus certain that the fungus, given entry, can extend the damage without any further intervention by frost. The course of the disease in some infected areas suggests that this may well happen naturally in the forest.

So far we have been lucky to have so few needle-cast diseases of conifers doing any serious damage. It is possible that needle-cast may form part of the disease pattern in the die-back of Norway spruce and Corsican pine mentioned above. But of the true leaf casts only *Phaeocryptopus gaumannii* on Douglas fir, and *Lophodermium pinastri* on Scots pine, can be considered at all serious. *Rhabdocline pseudotsugae* is really serious only on the Colorado strain of the Douglas fir, though it also occurs on the so-called Intermediate Douglas fir from the interior of British Columbia. The fungus is tending to kill out the Colorado Douglas, or, at any rate, to weaken it to such an extent that its removal becomes desirable; so that as the Colorado Douglas, which was never commonly planted, disappears, this disease becomes of decreasing importance.

It is still difficult to evaluate the real effect of *Phaeocryptopus* on Douglas fir. In the few instances where attack is severe it has certainly had a very definite effect on rate of growth. But though there is some evidence to suggest that slight and moderate attacks have affected the growth rate of the trees concerned, it is not conclusive. Numbered trees are still under annual observation in Wales and South-West England.

Lophodermium, though always a common fungus, and occasionally damaging to nursery stock, has not, in the past, done much recorded damage in plantations. In the spring of 1951, however, probably as a result of the wet weather during the preceding nine months, severe attacks were reported from various parts of the country on crops of Scots and other pines up to twenty-five years of age. It is probable that the degree of attack will be less next season, though the large amount of infective material present may result in a second moderately heavy attack. On most trees the only effect is likely to be a reduction in growth rate; only trees already suppressed appear at all likely to succumb.

One other needle cast, *Meria laricis,* leaf cast of European larch, occurs mainly in nurseries. It is now much less prevalent than it was fifteen or more years ago, when much larger numbers of European larch were being raised, which were often grown for several years in succession in the same part of a nursery, with a consequent carry forward of infection.

Among the forest hardwoods, beech and ash are the only two which have serious stem diseases in the pole stage. Canker on ash has often been attributed to bacteria, but certainly requires further investigation. On beech, cankering and bark die-back can affect trees of almost any age from pre-canopy to really old trees. *Nectria* is often found on such injuries, but at Westbury, Murray has also found bacteria to be generally present, and at the moment it looks as if several complex and possibly inter-related diseases go to make up this general group of bark diseases of beech. Work on them is still largely in the observational stage. Curiously, the most serious diseases of hardwoods are on trees such as elm and poplar, which seldom occur in large plantations, and on sycamore under open grown conditions. But this is almost the sole resemblance between these three diseases. Elm disease is a vascular wilt, bacterial canker of poplars a cankerous die-back, and the Sooty Bark Disease of sycamore a cambial die-back, usually too rapid in its extension to allow appreciable canker formation.

Elm disease is now becoming a familiar sight, and if it were not for its habit of flaring up in different areas each year, it would probably by now pass almost unnoticed. In 1950 the Isle of Sheppey was one area that was badly attacked for the first time, though the disease had certainly occurred there, much less seriously, in previous years. Now that the slow progress of the disease has been under observation for so long, the continuation of annual surveys, interesting though they were, appears unnecessary in view of the pressure of other work. Experiments, in other countries, on systemic fungicides will be watched with interest, as will any further work that is done on spraying with insecticides to prevent the bark beetles from infecting the tree, when feeding. But although experiments in this country on the latter were generally successful in 1948, 1949 and 1950, the cost renders both spraying and the use of systemic fungicides out of the question on large trees.

The question of varietal resistance is certainly worthy of continued attention, but it would probably be a mistake to do much on it in this country, unless it could be approached on a large scale basis. Dutch and American experience has shown that only a very small proportion of any batch of mixed seedlings will show any useful resistance, so that large numbers must be tried if results are to be procured. Work on this line has been confined to reducing still further certain pre-war stocks of possibly resistant elms. None can yet be regarded as proven. In addition a number of Swedish polyploid elms have been tested, all of which have proved highly susceptible.

Poplar canker, on the other hand, demands that even more attention be given to infection experiments, for no new hybrid or selection can be used with confidence, until it is known to be resistant to bacterial canker. So far our testing technique has been imperfect. Natural infection from cankered sets to test plants has been very infrequent, possibly owing to the amount of canker-free growth that the sets made under nursery conditions, and inoculations with bacterial slime have not given the percentage of takes that was expected. However, some useful information has already been collected, and plans are under way to extend the work next season, using cuttings, which will be easier to handle, and confining natural infection work to an area of infected suckers, into gaps in which test plants will be inserted.

Poplar canker suffers from the same handicap as work on Watermark disease of Cricket Bat willow, namely that the means of transmission from tree to tree is not known. If this could be discovered, it would probably throw light on certain anomalies affecting susceptibility and resistance which now exist.

In the nursery, diseases such as oak mildew and damping off are a constant irritant, though the former is easily controlled by spraying. Damping off does not occur with sufficient regularity in any one nursery to justify expensive soil sterilization, unless this can also be recommended on other grounds, such as improved seedling growth or weed control. But experiments have been started, in conjunction with Plant Protection Ltd., on seed treatment, which, if successful, would be financially feasible. *Keithia thujina* appears best controlled by growing plants from seed sown in isolated nurseries. The nurseries, where experiments on this method are under way, are still free from the fungus after three seasons.

1950 did not provide a heavy infection of *Botrytis cinerea* on Douglas fir or Sitka spruce in heathland nurseries so that the experiments which were designed to try out various substances, said to be of value in *Botrytis* control on other crops, were more or less a failure, and will have to be repeated. This is a pity, for in recent years this has been the most serious disease in our nurseries.

In general therefore we have a state of affairs in which there is no disease that can be considered an immediate threat to any one section of British forestry, but in which there are several diseases whose potentialities are still obscure, and on which further and more detailed work is an urgent necessity. Inevitably, since we are so largely concerned with planting land which is unsuitable for agriculture, and sometimes doubtfully suitable for forestry, trees often start with an initial handicap, which may well in itself be directly pathological. Our lack of knowledge of the effect which these adverse conditions have on the tree is a great handicap in the investigation of fungal and bacterial disease, but it is certainly idle to suppose that if all our trees were planted under ecologically ideal conditions, no disease would exist.

FOREST ENTOMOLOGY

By H. S. HANSON
Forest Entomologist

The subjects investigated by the entomological staff during the year are described in detail below.

The Green Spruce Aphis, Neomyzaphis abietina Walker

Historical

The Green Spruce Aphis was first described by Walker in 1846 as *Aphis abietina*, and is referred to by that name in Buston's *Monograph of British Aphides* (1877).

In 1913 Van der Goot placed the species in his new genus *Myzaphis*, but Theobald (1926) drew attention to the fact that Van der Goot cited Kaltenbach's *rosarum* as the type of the genus, and pointed out that as *rosarum* is a *Capitophorus*, *Myzaphis* must sink as a synonym of the former; a new genus *Neomyzaphis* was named for *abietina*.

Theobald refers to finding the insect near Odde in Norway in 1892, and abundant on Norway spruce at Kingston-on-Thames in 1899, and stated that the aphis swarmed and did much damage at Aberglaslyn in 1906. He also recorded it from Worksop, 1910, and from Kent, 1911, but stated that since 1846 the only years in which severe damage had been noticed were 1906 and 1913. By that date a very severe attack occurred on spruce trees of various kinds, and the insect had become well established in most parts of Britain and northern Ireland. It has since been recorded as causing damage in Austria, Germany, Holland, Canada, North-western United States and New Zealand.

Description and Life-cycle

In the adult stage two forms of viviparous females occur, one wingless and the other winged, but no male has ever been recorded.

The wingless female is from 1 to 1.5 mm. (about one-twentieth of an inch) in length, is green, oval and convex, with a dark line on each side of the body. Head yellowish-green to fawn colour. Antennae about half the length of the body, pale yellowish-green, dark at the tips.

The winged female is slightly larger than the wingless form; antennae nearly as long as body, light brown. Abdomen bright green with two rows of four dark green spots on the upper surface, and four smaller and less distinct spots along each side. Wings large and much longer than the body.

Many species of Aphides over-winter as eggs, but there is no evidence of the existence of an egg stage in the case of *Neomyzaphis*. Propagation is entirely by the production of active young, and may continue during mild periods throughout the winter in very sheltered situations in the south. During the spring successive generations of wingless forms develop. The date of appearance of the first winged generation varies considerably, depending on local conditions. The earliest recorded date is March 20th, but as a rule winged females are most numerous towards the end of May and during June and July.

Detailed breeding experiments carried out by Cunliffe (1924) showed that wingless females underwent four moults, and winged females five moults, during their development, and on an average reached maturity in sixteen days, at a mean temperature of about 60°F. After reaching maturity, wingless females lived on an average another seventeen days during which time each produced an average of twelve young. The most prolific individual produced thirty-four young in twenty-five days. Breeding experiments recently carried out at Alice Holt confirmed the above observations, but showed that the rate of development and reproduction may vary considerably.

As a result of his breeding experiments, Cunliffe estimated the average rate of reproduction to be 1,200 per cent. in twenty-five days, but considered that reproduction must be much more rapid to produce an epidemic in the forest. But even at that rate of reproduction, in the absence of natural control factors, by the end of a favourable breeding season the living descendants of a single aphid would in the eighth generation number nearly 430 millions. Although eight or even more successive generations are quite possible during a favourable breeding season, various lethal factors, to which reference will be made later, preclude the possibility of such a high level of population development under normal forest conditions.

Host Preference

Most of the earlier records of *Neomyzaphis* mention Norway spruce as the infested host plant. Theobald (1914) regarded that species as the normal host plant, and stated that until recently he had not seen the insect on any other plant except Scots pine, on which he had on six occasions found it in numbers, and once on Weymouth pine at Wye, Kent. It seems probable that the insects were on pine by chance and not by choice, and it is unlikely that they were actually feeding on pines. Cunliffe (1924) tried to establish *Neomyzaphis* on various species of pine, silver fir, larches and Douglas fir, but failed to do so. Recent attempts to induce *Neomyzaphis* to feed on plants other than *Picea* have been without success, and all efforts to find the insect feeding on any plant other than *Picea* have been equally unsuccessful. Neither has any evidence been found to support the view that the insect may have an alternate host, all the available evidence suggests that this is not the case.

Not all species of *Picea* suffer equally from the attack of *Neomyzaphis*, and not only does the degree of attack vary considerably on different species, but the effects of attack of any given intensity may also differ according to the species concerned. The variability ranges from needle browning, with as a rule very slight defoliation in the case of Norway spruce, partial defoliation in the case of *Picea pungens* and several other species, to almost complete defoliation in Sitka spruce; but a few species appear to be almost immune from the effects of infestation.

The fact that Norway spruce is susceptible to very severe attack but does not appear to suffer to any appreciable extent from defoliation, although the needles often show considerable browning, seems to indicate that this species has developed a high degree of resistance to the effects of infestation, and tends to support the view that Norway spruce is the original and normal host of *Neomyzaphis*.

Fox-Wilson (1948) published the following list of host-plants recorded at Wisley, showing susceptibility to attack and degree of defoliation.

HOST PLANTS OF NEOMYZAPHIS ABIETINA

Table 29

Host Plant	Susceptibility to attack	Degree of defoliation
Picea excelsa, Norway spruce	+++	Slight; Needles brown
Picea sitchensis, Sitka spruce	+++	Complete
Picea pungens, Colorado spruce	++	Partial
Picea pungens, var. *glauca*	++	Partial
Picea pungens, var. *kosteriana*	++	None
Picea asperata, Dragon spruce	+	Slight
Picea glauca, White spruce	+	Very slight
Picea likiangensis, Li Kiang spruce	+	Very slight
Picea mariana, Black spruce	+	Partial
Picea smithiana, Himalayan spruce	+	Partial
Picea koyamai, Koyama spruce	—	None
Picea likiangensis, var. *purpurea*	—	None
Picea omorika, Serbian spruce	—	None
Picea orientalis, Oriental spruce	—	None
Picea polita, Tigertail spruce	—	None
Picea schrenkiana, Shrenk spruce	—	None

Degrees of attack:
Severe +++, Fairly severe ++, Slight +, Apparently immune —.

The above list may be regarded only as an approximate assessment of the relative susceptibility to infestation and degree of defoliation. The conclusions are doubtless based on limited data, and refer chiefly to specimens grown as ornamental trees under more or less isolated conditions. It is extremely difficult accurately to correlate susceptibility to attack with degree of defoliation, because in all cases of infestation the full effects do not become manifest until a later date. The reference to "complete" defoliation in the case of Sitka spruce is perhaps an over-statement as, in the absence of other adverse factors, *Neomyzaphis* is usually incapable of causing complete defoliation. Some of the species listed as "apparently immune" are in fact known to be susceptible to moderate infestation, as for example *P. omorika*. Similarly some of the species shown as being only "slightly" susceptible to attack may sometimes become quite heavily infested, but may be only slightly defoliated. *P. pungens* var. *Kosteriana* is listed as being susceptible to "fairly severe" attack, but is stated to suffer no defoliation, although this species does sometimes suffer from slight defoliation.

It seems probable that all the varieties listed are to some extent susceptible to attack, and each may doubtless form a more or less suitable host for *Neomyzaphis* in the absence of a more attractive species, but the majority undoubtedly do exhibit varying degrees of resistance to the effects of infestation and, as relatively few of the varieties listed have been grown on a large scale under forest conditions in this country, there seems to be ample scope for the selection of a variety or the development of a suitable hybrid, to replace Sitka spruce in localities where this may be considered desirable.

Infestation development

The initial infestation in a young plantation may begin by wingless females introduced on nursery stock, or at a later date by invasion of winged females from other sources. In either case, as reproduction is parthenogenetic, a single female would be sufficient to start a colony at any point if conditions for reproduction were favourable.

The pattern of *Neomyzaphis* infestation may vary considerably in different areas, according to the stage of population development within the areas concerned. In the early stages infestation may be very sporadic, and may occur on single trees or small groups of trees in scattered patches of very uneven size. At a later stage, as the colonies develop and spread, the patches of infestation converge and may sometimes be separated only by strips of uninfested or slightly infested trees, and in some cases isolated clumps or even single trees at intervals may remain uninfested for a time. Later these erstwhile apparently immune trees may be found to be heavily infested, while other previously heavily infested trees, which are now partly defoliated and are temporarily unsuitable, may be almost destitute of insects. In some cases different degrees of infestation may occur in more or less well defined zones, as a rule corresponding roughly with differences in elevation, aspect, exposure or relative proximity to adjacent crops. Finally the infestation may become generally distributed throughout the area. Differences in the pattern and degree of infestation also occur on the individual trees according to the stage of population development. If examined during the early spring just before the current year's growth begins, the trees in any infested plantation may be divided into the following categories:—

A. Branches fully clothed with healthy foliage showing no sign of *Neomyzaphis* attack.
B. Branches fully clothed, but with the older foliage bearing signs of infestation indicated by small yellow spots or patches, or individual needles entirely discoloured.
C. Branches not fully clothed. Previous year's needles intact but growth of former years badly discoloured, or partly defoliated.
D. Branches bearing only needles of the previous year, and completely destitute of needles of former years.

During the final stage of a very severe infestation the majority of the trees may be in the last condition.

Seasonal and Periodic Cycles

Although *Neomyzaphis* is capable of building up a very big population when conditions are entirely favourable, this seldom occurs, and is never of very long duration. Under normal forest conditions various combinations of lethal factors prevent uninterrupted population increase, and cause both seasonal and periodic cycles in the population density. Consequently several years may elapse before an initial infestation reaches pest proportions in extensive young plantations.

Observations in Fermyn Wood, Rockingham Forest, Northants., have shown how seasonal fluctuations occur in developing *Neomyzaphis* infestations. During the autumn of 1949 the Sitka spruce foliage was heavily infested, and there was every indication that severe defoliation might reasonably be expected if the *Neomyzaphis* population continued to increase. Heavy mortality occurred during the winter, and relatively few adult insects survived, but the population began to increase in the early spring of 1950. Metal labels were attached to a large number of the 1949 shoots, and the numbers of insects on each shoot were counted and recorded throughout the season to ascertain the rate of population increase; continuous observations were made to assess the relative importance of weather conditions and natural enemies, and their influence on population development.

During the spring of 1950 the weather was favourable, and the *Neomyzaphis* population began to build up rapidly as wingless females produced new generations. The first winged females completed their development during the first week in May and a slight decrease in the local population occurred as a result of migration, but the remaining wingless females continued to reproduce, and the population density increased until the end of the third week in May. By that time a strong predator and parasite population had developed; mortality began to exceed the rate of reproduction, and the *Neomyzaphis* population rapidly decreased and reached a very low level by the third week in June. During the summer, labels were also attached to shoots of the current year's growth, and these shoots were also kept under observation. Control by predators and parasites continued throughout the summer until the first week in September. By that date the predator population declined, the *Neomyzaphis* began to increase steadily, and a second peak of population density was reached by the end of November.

Throughout the winter reproduction took place during mild weather, but frost and snow caused considerable mortality during the first three weeks in December. A slight increase in the population occurred during the last week in December, but this was followed by a further decline during January. Mortality continued to equal the rate of reproduction during February and March, and the population remained at a low level of density without appreciable increase until the end of March. During the winter of 1950-51 the *Neomyzaphis* population was at its lowest during February and March, but even during that period it was slightly higher than at any time during July and August, 1950.

The cold wet weather during the spring of 1951 prevented any definite increase in the *Neomyzaphis* population until the last week of April, and increase was very slow during the next three weeks; in fact population density comparable with that of late November was not reached until the middle of May; but during the next three weeks the population increased very rapidly. In the meantime both predators and parasites had become very numerous, and by the end of the first week in June they began to exercise effective control; during the next two weeks increase in the *Neomyzaphis* population was at a much slower rate. By the last week in June mortality exceeded the rate of reproduction, and a rapid decline in the population occurred. By the middle of July population density was reduced to the level of late November, 1950, and by the end of July it was lower than at any time during the winter of 1950-51. But this state of complete biological control was reached more than a month later than in 1950.

In the meantime winged females had migrated from heavily infested trees and were observed to be reproducing on trees not previously infested during the current year, and on some trees the 1951 foliage was as heavily infested as the 1950 foliage just before the collapse of the population occurred.

The above observations show how seasonal fluctuations are caused by unfavourable weather during the winter, and by natural enemies during the summer, and how these factors retard the development of infestations.

The following observations illustrate how abnormal weather conditions may terminate an infestation and start a fresh periodic cycle. By the end of 1946, a heavy infestation of *Neomyzaphis* had developed in Alice Holt Woods in Glenbervie Inclosure. During the winter of 1946-47, conditions were very favourable for continued reproduction and, by the early spring of 1947, a strong *Neomyzaphis* population existed and a large proportion of the trees had only the previous year's foliage intact. In the late spring of 1947 a prolonged spell of icy conditions almost annihilated the *Neomyzaphis* population. During the succeeding years the build up of the population has been very slow, with seasonal fluctuations less pronounced than those observed at Fermyn Wood. In the meantime the trees have become fully furnished with foliage and, as a result of the wet but very favourable growing season of 1950 and spring of 1951, the Sitka spruce have made complete recovery, and are making exceptionally good growth. In this case it may be several years before the *Neomyzaphis* population can again reach the status of a heavy infestation.

Development and decline of *Neomyzaphis* infestations in periodic cycles have been observed in other localities. As a rule in older stands, in localities suitable for the development of infestations, periods of severe defoliation may occur at intervals of several years, but in the case of individual trees strong infestations may occur at much shorter intervals.

Fox-Wilson (1948) stated that observations made at the Royal Horticultural Society's Station, Wisley, over a period of twenty-five years, indicate that severe infestations occurred during the years, 1921, 25, 28, 33, 35, 38, 41, 43 and 1946. The above records refer to infestations on trees growing under horticultural conditions and, as each infestation was terminated by insecticide application, their incidence, and the conditions under which they developed, bear little if any relationship to the build up of population density over a period of years, culminating in severe defoliation so often associated with *Neomyzaphis* infestations under forest conditions.

Of the above dates, 1921, 1925, 1935 and 1943 were years in which peak infestations occurred and considerable defoliation was observed in Sitka spruce areas in various parts of the country. 1906 and 1913 were also peak years. These figures indicate that periodic peak infestations tend to occur at intervals of seven or eight years in Sitka spruce stands. During 1946 the infestation in Alice Holt Woods appeared to be approaching the peak stage, but, as mentioned above, abnormal climatic conditions terminated the infestation. On the other hand considerable defoliation did occur during 1949 and 1950 in many localities.

As ecological conditions differ considerably in various parts of the country, the pattern of population development and intensity of infestation also vary, and the occurrence of a periodic peak with severe defoliation is by no means inevitable in any locality.

Natural Control

Observations throughout the year have shown that at low elevation in this country, there is no definite hibernation period in the life cycle of *Neomyzaphis*, but although reproduction takes place during mild weather, adverse weather conditions play a very important part in retarding population development, while most natural enemies are inactive during the winter and early spring. On the other hand, in localities where weather conditions are entirely favourable for the rapid increase of *Neomyzaphis*, during late spring and throughout the summer, the rate at which infestations may develop and terminate is largely determined by the abundance and activities of natural enemies, of which parasitic and predatory insects, and spiders, are by far the most important, particularly during the early stages of the crop's development.

The exact economic status of insectivorous mammals and birds, in relation to *Neomyzaphis* control, is very uncertain, and remains largely a matter for conjecture. Theobald (1914) records that he observed Long-eared Bats feeding on both winged and wingless females, on and around a single large spruce tree standing in his garden, and other species of bats no doubt readily do so. It is, however, unlikely that bats are ever sufficiently numerous to effect an appreciable degree of control in extensive Sitka spruce plantations, although it seems probable that their increase might be facilitated by the provision of suitable hibernation quarters.

Tits and other insectivorous birds have been observed searching the foliage of infested Sitka spruce trees during the winter, but it is doubtful whether their activities are entirely beneficial. The various species of Hymenopterous parasites overwinter in dead aphides attached to the needles and, because of their colour and swollen appearance, these parasitized aphides are very conspicuous and particularly vulnerable to the attack of birds during the winter. It is therefore conceivable that birds might even reduce the ratio of the parasite population at this stage. On the other hand it is quite certain that both birds and bats destroy large numbers of small moths and, as several species are rapidly becoming serious pests in Sitka spruce plantations, birds and bats should be encouraged in every possible way.

The inter-relationships of and possible methods of facilitating the work of natural control factors, are the subjects of further detailed investigation.

Other Pests of Sitka Spruce

As *Neomyzaphis* does not normally attack the current year's foliage of Sitka spruce until late in the season, and causes no appreciable damage to the needles until late spring of the following year, by which time another year's growth has begun to develop, this species is incapable of causing complete defoliation in the absence of other adverse factors. On the other hand, several other pests concentrate their attention on the current year's growth. These pests include several species of large Aphides of the *Lachnid* type, also *Adelges strobilobius* Kalt, and *A. abietis* L. and in some northern localities *A. cooleyi* Gill., also the larvae of several small moths and sawflies. Any of the above pests, when numerous, may cause severe damage to the current year's growth and, collectively, they are capable of causing the complete destruction of the current year's foliage. Consequently, in the case of a peak infestation by *Neomyzaphis* causing defoliation of all former years growth, the simultaneous attack of several of these pests may result in complete defoliation and the death of the trees, particularly in localities where they are subject to damage by frost, excessive smoke, or sea blast. In some localities the situation may be aggravated by the Conifer Spinning Mite, *Paratetranychus ununguis* Jacobi., especially in young plantations growing under unfavourable conditions.

The forest relationship of each of the above pests is being investigated as opportunities occur.

Survey of Sitka Spruce Pests

A general survey of representative Sitka spruce crops growing under various combinations of ecological conditions is being carried out, to study the development of pest infestations in relation to the influence of locality and cultural factors in various parts of the country. A census form has been circulated to all Conservators, and the scheme is receiving their full co-operation. Completed forms have been received and it is evident that the census is yielding very valuable information. The completed forms will be used as a basis for the selection of areas, in which detailed assessment will be made of locality factors and their influence on infestation incidence and development. In certain selected areas representative sample plots will be prepared in which data may be collected by the local forest staff, on lines to be prescribed, to record from year to year the progress of infestation development and its effects on the rate of height growth of the crop.

Sawfly Survey

The Large Larch Sawfly, Pristiphora (Lygaeonematus) erichsonii Hartig.

In certain areas where intensive collection of larvae and cocoons took place during the previous year, a slight check in population development appears to have been caused. At Thirlmere, Cumberland, only eighty-five trees were observed to be infested in 1950, as compared with one-hundred and fifteen during the season 1949, and at Radnor Forest, Radnorshire, only nine colonies of larvae were found in 1950 as compared with eleven colonies during 1949. On the other hand, a considerable increase in the population occurred at Mortimer Forest, Herefordshire, where forty infested trees were located in 1950 as compared with only fourteen in 1949. In both these areas the infestation was widely distributed. At Mortimer most of the infested trees were Japanese larch, but at Thirlmere both European larch and Japanese larch were attacked, the infestation being chiefly on the east side of the lake. In Thornthwaite Forest, Cumberland, thirty-five colonies of larvae were found in a plantation of ten-year-old Japanese larch, on the east side of Lake Bassenthwaite. Several private estates were visited in other parts of the Lake District, and larvae of the Large Larch Sawfly were found in all areas visited. Light infestations ranging from one to eight colonies of larvae were also found in each of the following localities; Brecon and Crychan in South Wales, Kershope in North-west England, Slaley, Chopwell, Warke and Harwood in North-east England. Newcastleton and Wauchope in South Scotland. Heavier infestations ranging from 20, 21, to 34 colonies of larvae were found at Redesdale, Rothbury and Kielder in North-east England. In the last-named area larvae were found feeding on quite small Japanese larch in fire belts planted in 1948.

The figures for the 1950 survey indicate that the Large Larch Sawfly is definitely on the increase over a very wide range. This is confirmed by observations in Alice Holt Woods, where in 1949 a single colony was reported, and only two colonies could be found in 1950; but by the end of June this season no fewer than thirty-five colonies of larvae were found in various parts of the area.

The Small Larch Sawflies

Of the small larch sawflies, *Anoplonyx* (=*Platycampus*) *duplex* Lep. was again found to be the most numerous species in many localities. Although the original infestation at Craig Vinean near Dunkeld has declined, partly because of parasites and possibly because of disease, other infestations in the locality are still developing. A strong infestation was also reported at Drumtochty Forest, Kincardineshire, and several thousands of the parasite *Dahlbominus* (*Microplectron*) *fuscipennis* Zett. have been liberated in the area.

A strong infestation has also developed on twenty-two-year-old Japanese larch in Compt. L. 14/15 in Radnor Forest, but severe damage to foliage occurs only over a relatively small area.

The infestation by *Pristiphora* (=*Lygaeonematus*) *westmaeli* Tishb. at Grizedale Forest, Lancashire (in Compts. 7, 9, 10 and 11, all sixteen years old)—reported in the previous year, was still on the increase. In 1950 infestation was most severe on Japanese larch (in Compts. 42/43) where nearly every tree examined showed damage by the larvae, including the foliage of vigorous leading shoots. This species is widely distributed, particularly in the north of England, where it was first recorded in 1919. Considerable damage by this insect was recently reported on a private estate near Wakefield in Yorkshire.

Spruce Sawflies

The infestation by *Pristiphora* (*Lygaeonematus*) *subarctica* Forr. on Norway spruce in the Forest of Dean, Glos., appears to be on the decline, and very slight defoliation was caused during 1950.

Pristiphora abietina Christ and *Gilpinia hercyniae* Htg. were still numerous and widespread, but no severe infestations by either species was reported.

Pristiphora ambigua Fallen, and *P. amphiloba* Foster larvae were numerous on Sitka spruce in some localities, including Alice Holt Woods, where they caused considerable wilting of young shoots in some compartments.

Parasites of Sawflies

Several species of Hymenopterous parasites were bred from cocoons of sawflies collected in various localities.

Megastigmus Parasite Survey

It has long been known that in many localities seeds of Douglas fir are infested and destroyed by the larvae of the Chalcid seedfly *Megastigmus spermotrophus* Wachtl, and that the seeds of many other coniferous trees are attacked by similar species belonging to the same genus of insects.

As seeds intended for sowing are normally collected before the larvae of *Megastigmus* are attacked by parasites, the usual seed testing methods give no definite information as to whether parasites are present in the localities where the seeds were collected, although the exceptionally high proportion of infested potentially sound seeds, in some samples reaching 100%, seems to indicate that no efficient parasite exists in the area from which these particular seeds came, and suggests the desirability of introducing suitable parasites for the biological control of the pest.

For the purpose of ascertaining whether parasites of *Megastigmus* actually exist in this country, a preliminary survey has been made. In the spring of 1951 numerous samples of Douglas fir and other coniferous seeds were collected in Forestry Commission areas and on private estates in various localities from the south of England to north-east Scotland, and parasites have been bred from seeds collected from several localities.

Parasites of the Pine Shoot Tortrix

In 1936 several thousand specimens of a polyembryonic *Chalcid* egg parasite, *Copidosoma geniculatum* Dalm., were imported from Austria by the Imperial Institute of Entomology for liberation in Forestry Commission areas for the control of heavy infestations of the Pine-shoot Tortrix *Rhyacionia* (*Evetria*) *buoliana* Schiff. The number of parasites liberated was:—

3,000 at Wareham in Dorset
2,400 at Rendlesham in Suffolk
2,000 at Tunstall in Suffolk

The Tortrix infestations in these and other areas subsequently collapsed, chiefly as a result of the resident parasite population. No attempt has since been made to ascertain whether the imported parasites survived, and as this information is desirable, collections of Tortrix-infested shoots have now been made in these and other areas in south-east England where recent infestations have begun to develop. Parasites are being bred from the collected material, and a list of these will be prepared in due course, showing the percentage of parasitism by each species in each area concerned. The results to date show that *Copidosoma* has survived at Rendlesham, as this parasite has been recovered from the material collected in that area.

In 1937 several thousand specimens of a pupal parasite *Tetrastichus turionum* Htg., also imported from Austria, were liberated at Puddletown, Wareham Forest, Dorset. As the Tortrix infestation appears to have died out completely, infested shoots could not be collected in this area, but it will be interesting to know whether the parasite has become established at Wareham.

Insecticide Experimental Work

Laboratory and field tests were continued with various insecticides for the control of *Neomyzaphis* and other aphid pests on Sitka spruce, and *Adelges* on larch. Some of the highly toxic contact insecticides cause a certain amount of scorching effect on the foliage, and are considered too dangerous for general use.

Preliminary tests with systemic insecticides gave promising results in small scale experiments, under both laboratory and field conditions. This line of investigation is being continued and extended to include both direct and indirect root application.

Laboratory tests with various insecticides for the control of weevils and bark beetles were continued, and many thousand pine weevils were used for this purpose. Benzene hexachloride yielded 100% mortality under laboratory and similar conditions, but the results of a trapping experiment in the New Forest showed that benzene hexachloride had considerable deterrent properties and, although this substance can be used for protecting young plantations growing adjacent to *Hylobius* and *Hylastes* breeding grounds, it is unsuitable for use in traps.

Further efforts are being made to find an insecticide with attractant properties suitable for weevil traps, the object being to poison the weevils and avoid the cost of collecting them.

Sirex Parasites for New Zealand

During the year substantial numbers of the *Cynipid* parasite *Ibalia leucospoides* Hochnw., in various stages of development, have been collected and sent by air to New Zealand for the control of *Sirex* wood-wasps in the extensive coniferous forests. The New Zealand Government has requested that the work be continued on an increased scale during the coming season.

Consultative and Advisory Work

Visits were paid to several areas to examine insect infestations, and 83 enquiries have been dealt with, 45 from Forestry Commission areas and 38 from private estates.

MACHINERY RESEARCH

By R. G. SHAW
Machinery Research Officer

The Mechanical Development Committee at Headquarters continues to direct investigation into the major projects on machinery development. Similar committees have been formed in each of the Directorates for the examination of new ideas which are passed to Headquarters where they appear to be worth trial.

The main emphasis of the work during the year has been on the various aspects of extraction, and a large scale trial of all available extraction equipment is taking place in the Border Forests during the summer of 1951. Progress has been made during the year as follows:—

British Tractors

In the heavy tractor class, an order has been placed for a Fowler Marshall Challenger III to be used for road construction, and delivery is expected before the end of 1951. A number of ploughing tractors have been investigated, and the Fowler Marshall V.F. has been accepted and is now coming into general use. This tractor does not give a performance quite equal to that of the Caterpillar D.4. and International T.D.9., of which the ploughing tractor fleet is mainly composed, but it is a suitable alternative in most areas.

Another Fowler Marshall (the 50 h.p. Challenger I) is expected to be on trial, mainly for ploughing, by the autumn of 1951.

The increasing area of very soft ground in the annual ploughing programme has directed attention to the development of special tractors with very low ground pressure. One Cuthbertson tractor with a ground pressure of under 2½ lb. per square inch is on trial in Scotland, and another design with a similar ground pressure is under examination.

Ploughing

Development of ploughs for draining and planting has continued. An interesting experiment is taking place in Scotland with the mounting of a plough on a tracked tractor. Hitherto mounted ploughs have been confined to wheeled tractors, but progress has been made towards overcoming the difficulties of adapting them to tracked machines.

Cableways

Cableway development has been confined to the power-operated type, in which a carriage runs on a single cable in conjunction with a power-operated hauling winch. Progress has reached a stage where four men can handle two tons per hour on a 300 yd. cable, after the logs have been assembled at convenient loading points.

Chutes

Trials of aluminium chutes have continued during the year, but no final conclusions have been reached. Controlling the speed of the logs in the chute is one of the problems. It has been found that chutes are very sensitive to conditions, not only of slope, but also of weather and species. A chute which will operate perfectly well on one day, which happens to be dry, may be unsatisfactory on the next day if it is raining, due to the great increase in the speed of the logs. A similar difference in speed may be shown by a change from one species to another. Very high speeds must be avoided, owing to the tendency of the logs to jump out of the chute, and also to damage it.

For short runs where the ground is not broken, the aluminium chute is very attractive, owing to the ease with which it can be moved from one site to another.

Bark Peeling

Considerable success has been attained by the Coles machine for bark peeling, during conversion of small diameter poles into stakes prior to creosoting. This machine consists of a high speed cutting head under which the log is fed mechanically. The capital cost is high (£800) and the machine is only suitable in cases where it can be kept in regular use. Smaller machines, on the chain beating principle, have not proved to be an economic proposition. Experiments in the removal of bark by shot blasting have been carried out, and in a bench test the results were encouraging; but it is also clear that the use of this method on a commercial scale would involve a large and expensive plant, and nothing beyond a rig test has been undertaken.

Clearance of Derelict Woodland

Two methods of clearance by mechanical means are being tried:—

(*a*) Grubbing with a special rooter blade.

(*b*) The use of a giant Rotavator to break up and bury waste material.

Method (*a*) has been in commercial use for some time for the recovery of land for agricultural purposes, but it has not yet reached an economic price for reafforestation.

Method (*b*) is in the very early stage of development.

Haulage over Soft Ground

The increasing areas of very soft ground to be planted are providing problems for load-carrying vehicles in roadless areas. The only solution is to use tractors and trailers, but the latter have to be of a special type in that they must have a ground pressure not very much more than the tractor. Tracked trailers offer a solution, but they are expensive and their maintenance costs are high. A multi-wheeled trailer with low-pressure tyres has been designed, and it will shortly be on test.

Road Haulage

It continues to be the Commission's policy to use standard commercial vehicles as far as possible, including a limited usage of four-wheel drive types. The only specialised vehicle which has come into general use during the year is the two-wheeled trailer which has been designed to allow standard lorries to carry long poles with safety. The object of using this trailer is that it reduces the need for special articulated vehicles, which can be used in no other role.

Fire Protection

Tests have been carried out on a self-pressurising back pack extinguisher. The object was to relieve the operator of the need for hand pumping, as is necessary in the present back pack extinguisher. Owing to the increase in the weight of the extinguisher needed to withstand pressure, the volume of water carried was reduced to little more than half. Tests have shown that the advantage of the operator having both hands free did not compensate for the reduction in available water.

Pressure was provided by replaceable carbon dioxide cartridges.

Mechanisation of Nursery Operations

Development is taking place on machines for the application of formalin and various weed-killers to nursery seed beds.

Machines for root pruning have been tested, and some success has been attained; attention is being given to reducing the amount of disturbance to the seedlings.

Loading

Some plantations have already reached the stage where loading of thinnings onto lorries is beyond hand methods. The H.I.A.B. Hoist, which is of Swedish origin, has been tested and found successful, and it has now been adopted on a number of timber-carrying vehicles. The H.I.A.B. is a hydraulically operated crane, which is fitted to the lorry and can be brought into use in a matter of a few seconds.

PHOTOGRAPHY

By I. A. ANDERSON
Senior Photographer

After nearly two years of existence, the Photographic Section is now organised on the lines along which it should proceed. It is evident, judging from last year's operations, that increasing use will be made of this branch, and the possibility of expansion should be envisaged. The work we have done for various Conservancies, in connection with annual fixtures only, such as the Royal Counties and the Highland Shows, makes it plain that we may expect more of this type of pictorial work, in addition to our day-to-day routine. The backlog of old work has however been cleared, and we may now reasonably expect to be able to deal with any work we are asked to do.

Central Collection

Photographically the collection is now up to date; current work being added as the photographs are taken. Work on the backlog of negatives was completed in the past year. These were treated selectively, and although some of poor photographic quality have been retained in the collection, they are included only for their value as a record of the earlier experiments and plantings. The total number of photographs now in the collection is some 4,500.

Classification and Indexing

The Central Collection is not yet in a "working state", as there has been considerable difficulty in the classification and indexing of the photographs. Some 2,000 have been dealt with so far, and we should be up to date within the next eighteen months. Difficulty in classification has been encountered mainly with the older photographs, as descriptions were often brief.

Programme of Outside Work

It is gratifying that more use is being made of the photographic section by the Conservancies. It is to be hoped that as the value of photography in forestry becomes more apparent, these demands from the Conservancies will increase.

Experimental Work

Following on the experiments commenced last year, we have now standardised our chemicals and materials, and consequently, most of the experimental work this year has been in the medium of colour. Here again, we have now standardised the best materials it is possible to obtain in this country, though it is to be regretted that some of the finest colour emulsions which have been developed in the United States are denied us. Ektacolor particularly would be of great use to us, as it would cut colour printing time by about two-thirds (elimination of the separation negative stage). In addition, as many colour transparencies as are required (for lectures, etc.) can be made in any size by projection or contact from the one colour "negative", without any loss in colour balance, or saturation of colour. With materials currently available there is an unavoidable loss in duplication. Nevertheless, we have had considerable success in increasing the effective emulsion speed of the subtractive integral tri-pack best suited to our needs.

LIBRARY AND DOCUMENTATION WORK

By G. D. KITCHINGMAN
Documentation Officer

Books Section

The number of books in the Library increased from 1,320 to 1,545. Of these, 249 are on permanent loan to sectional libraries. Loans from the Lending section increased from 381 to 526. Only 12 books were classed as "Missing" at the close of the year.

Periodicals Section

90 Volumes of periodicals were bound, bringing the total to 881.

Information Files

These files are increasing slowly, but there is still a great deal of loose material awaiting documentation and filing.

Cataloguing Work

A catalogue of books in the Lending Library on 31st March, 1950, has been printed. Included in this catalogue is a list of the periodicals held in the library, and a list of the Forestry Commission Publications issued from 1919 to 1950. This catalogue should be most useful to out-station borrowers, and it will save much of the library staff's time replying to questions whether a book is in the library or not.

Documentation Centre

The number of cards in the indices is now about 26,000, but this work is in arrear. Requests for literature on special subjects from officers writing papers or giving lectures is increasing. This is encouraging as this is undoubtedly the best service a well-documented library can provide. In all scientific research centres today, the need for some process of sifting and sorting the wealth of literature is so keenly felt that documentation work is gaining in importance.

Library Quarterly

Four numbers of the *Quarterly* were issued during the year. The four library Records issued with it dealt with the literature of:—

(1) Silviculture in the U.S.A.
(2) The Red and Grey Squirrels.
(3) Forestry in Scotland, and
(4) Sitka Spruce.

Aslib

Close contact has been maintained with the Association of Special Libraries and Information Bureaux, of which the Library is now a member. The Librarian attended meetings to co-ordinate translation work and the locating of little-known periodicals.

PUBLICATIONS

The following papers were published by members of the Research Staff during the year.

BATKO, S.	A note on the distribution of *Poria obliqua* (Pers.) Bres. *Transactions of the British Mycological Society*. Vol. 33. pps. 105 and 106 (1 photograph).
CHRISTIE, J. M.	A note on three Sycamore sample plots in South East England. *Quarterly Journal of Forestry*. Vol. XLV. No. 4. October, 1950. p. 214.
HUMMEL, F. C.	Interim note on a thinning study in young pine in East Anglia. *Forestry* Vol. XXIII, No. 2. 1950.
HUMMEL, F. C.	The silviculture of mixtures in the forests of Salem, Zeil and Mengen. *Quarterly Journal of Forestry*, Vol. XLV, No. 1. January, 1951. p. 23.
HUMMEL, F. C.	Instruments for the measurement of height, diameter and taper on standing trees. *Forestry Abstracts*, Vol. 12, No. 3. 1951.
HUMMEL, F. C. and WATERS, W. T.	*General Volume Table for Oak in Great Britain.* Forest Record No. 5. 1950. (H.M.S.O. 4d.)
HUMMEL, F. C. and WATERS, W. T.	*General Volume Table for Beech in Great Britain.* Forest Record No. 6. 1950. (H.M.S.O. 4d.)
HUMMEL, F. C. and WATERS, W. T.	*General Volume Table for Birch in Great Britain.* Forest Record No. 7. 1950. (H.M.S.O. 3d.)
HUMMEL, F. C., IRVINE, T. W. and JEFFERS, J.	*General Volume Tables for Scots pine in Great Britain.* Forest Record No. 8. 1950. (H.M.S.O. 9d.)
HUMMEL, F. C., IRVINE, T. W. and JEFFERS, J.	*General Volume Tables for European larch in Great Britain.* Forest Record No. 9. 1950. (H.M.S.O. 9d.)
HUMMEL, F. C., IRVINE, T. W. and JEFFERS, J.	*General Volume Tables for Norway spruce in Great Britain.* Forest Record No. 10. 1950. (H.M.S.O. 1s.)
KEEN, E. A.	The Relascope. *Empire Forestry Review*. Vol. 29, No. 3. 1950.
MACDONALD, J.	Tree Planting for Shelter. *Journal of the Yorkshire Agricultural Society*. No. 101. 1950.
MACKENZIE, A. M.	Douglas fir Sample Plots at Beaufort, Inverness-shire. *Scottish Forestry*. Vol. 4, No. 4. October, 1950.
MATTHEWS, J. D.	Precocious Scots pine. *Quarterly Journal of Forestry*. Vol. XLIV, No. 4. (Oct., 1950.) pp. 237-8.
MATTHEWS, J. D.	Forest Genetics (Report of the British Association Meeting in Birmingham, 1950). *Nature*. Vol. 167 (1951). p. 764.
MATTHEWS, J. D.	Forest Tree Breeding in Great Britain. *Y Coedwigwr*. Vol. 1, No. 3. 1950. pp. 71-4. (University College, Bangor.)
PEACE, T. R.	Poplar as a Farm Crop. *Agriculture*, Vol. 57, No. 473. 1951.
WOOD, R. F. (and others)	*Guide to the National Pinetum and Forest Plots at Bedgebury*. 1951. (H.M.S.O. 2s. 6d.)
WOOD, R. F.	Some Notes on Current Silvicultural Research in the Forestry Commission. *Sylva*. No. 31. p. 16. 1950-51. (Edinburgh University).

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

SUB-COMMITTEE ON NUTRITION PROBLEMS IN FOREST NURSERIES. SUMMARY REPORT ON 1950 EXPERIMENTS

By Dr. E. M. CROWTHER and Miss B. BENZIAN
Rothamsted Experimental Station, Harpenden, Herts.

1. Introduction

In 1950, several series of experiments were continued and new ones laid down at the following nurseries:—

(1) Old Kennington, near Oxford—old established nursery.
(2) Kennington Extension, near Oxford—taken over from arable land in 1945.
(3) Bagley Wood, near Oxford—a clearing in a coniferous forest.
(4) Sugar Hill, Wareham, Dorset—heathland.
(5) Ringwood, Hants.—old established nursery.
(6) Ampthill, Beds.—old established nursery.

A few experiments were continued in six other nurseries, and a series of test-demonstrations was established at several Conservancy Nurseries.

Most of the experiments were on one-year seedlings of Sitka spruce, a most sensitive species. At each of the principal experimental centres, seedlings raised in 1949 were transplanted in extension experiments, and both seedlings and transplants were planted out in two forests in Wales. There were also several experiments on the manuring of transplants and newly planted trees.

2. The 1950 Season

Although the spring and early summer of 1950 were dry, heavy rainfall in late summer and autumn allowed good growth in most of the nurseries. In the principal experimental nurseries many of the treatments gave very large seedlings and transplants, showing marked effects of treatments. This was in striking contrast to the results obtained in the three preceding seasons, growth having been severely checked by droughts in 1947 and 1949, and by late sowing and low temperatures in 1948. The good growth of 1950 made it possible to study many important questions on which the data had been inadequate in the three preceding years. Some of the 1950 experiments brought out so many significant effects and interactions that detailed tables are required to illustrate the main results. The fact that much information had been lost through droughts, raises the question whether it would pay to develop overhead irrigation in some of the research nurseries, to the stage at which it might be used systematically in part of the experimental programme.

In 1950, many of the nurseries on light soils showed large benefits from nitrogen and potassium fertilizers, but the effects of phosphorus fertilizers on size and on colours were less than in the drought years. These results are to be expected on general grounds. The improvement of early root growth by phosphorus fertilizers is more important in dry years than in wet ones, but there is a considerable risk in a wet season of losing soluble nitrogen and even potassium compounds from light acid soils. In the autumn of 1950, the seedlings in several of the nurseries on light sandy soils showed signs of insufficient supplies of nitrogen and potassium, even where these elements had been supplied earlier in the year. One of the most difficult problems in manuring forest nurseries is to work out reliable rules for adjusting the application of nitrogen fertilizers to fit seasonal weather conditions.

3. Composts and Fertilizers in Seedbeds

Experiments in many nurseries over several seasons have failed to reveal any consistent difference between seedlings raised with fertilizers and those raised with composts, provided adequate amounts of nitrogen, phosphorus and potassium are given. The behaviour of seedlings or transplants in the forests was substantially the same for plants raised with compost and those raised with fertilizers. Several new series of experiments, started in 1950, included further comparisons of inorganic fertilizers against a standard compost made from bracken and hop waste. If plots treated with formalin are omitted, the 1950 results showed that slightly larger plants were grown with fertilizers than with compost in seventeen out of twenty-three comparisons. On the evidence so far obtained, there appears to be little justification for heavy expenditure on composts for forest nurseries. Many of the experiments already in progress will be continued for a number of years to see whether any cumulative effects build up from repeated treatments.

In 1950, a series of long-term test-demonstrations was started at four large Conservancy Nurseries, to test the effects of compost, fertilizers, and both, on two species of conifers. In the first season, growth of Sitka spruce was poor in three of these nurseries, and there were only small and irregular differences between the effects of fertilizers and composts.

A third-year experiment at Bagley Wood, with repeated manurial dressings on Sitka spruce sown each year, tested different kinds of compost (5 lb. per square yard), prepared under experimental control at Kennington Nursery, and also a number of raw organic wastes. Each organic material was tested alone and in conjunction with an NPK fertilizer and compared with the NPK fertilizer alone at two rates of application. The 1950 results are given in Table 30 below:

THIRD YEAR EXPERIMENT WITH REPEATED TREATMENTS,
AT BAGLEY WOOD NURSERY

Table 30 One year Sitka Spruce, sown 1950 Height in inches

	Used alone	With additional Single NPK fertilizer
Composts prepared from		
Hop waste	1.8	3.3
Bracken + hop waste	1.8	2.7
Straw + hop waste....	1.9	3.1
Straw + inorganic fertilizers	2.6	3.2
Straw + organic fertilizers	2.8	3.4
Bracken + superphosphate	1.8	2.9
Raw materials		
Hop waste	1.9	3.2
Straw + NP fertilizers	1.9	2.7
Bracken + superphosphate	2.3	2.7
Standard error	±0.18	±0.18
No organic manure		
No fertilizer....	1.4	—
Single NPK fertilizer	2.4	—
Double NPK fertilizer	3.1	—
Standard error	±0.13	—

For tests on organic manures used alone, the outstanding materials were composts prepared from straw; but none of the composts and raw materials, used alone, gave plants as good as those from the double rate of fertilizer. With all organic materials there were large improvements from additional fertilizers, the improvements being particularly great with hop waste compost and fresh hop waste, materials known to be good sources of N and P but deficient in K.

There is so far no sign in the third season that the fertilizer plots are suffering through lack of organic matter.

4. Crop Rotations

The results of the rotation experiments at Kennington Extension and Wareham have not yet proved consistent enough to justify any statement of the relative effects of clover, rye, ryegrass, lupins and bare fallow, once in three years, as alternatives to continuous cropping with Sitka spruce. Experiments on these subjects must be continued for several years before any reliable conclusions can be drawn.

Preparations were made in 1950 at the Wareham and Kennington nurseries for starting, in 1951, long-term rotation experiments comparing composts and fertilizers, and also testing the effects of various leys and green crops in the cropping rotation. Special precautions are being taken to prevent any spread of soil from plot to plot.

7. Fertilizers in Seedbeds

In an experiment started in 1949 at Bagley Wood, and repeated in 1950, on one-year Sitka spruce seedlings, there were very large responses to fertilizers, with marked colour symptoms due to nutrient deficiencies on many of the plots from which individual nutrients were deliberately omitted. The extreme range in mean height per plot was from 1.0 to 2.5 inches. In this experiment it was possible to show that phosphorus and potassium fertilizers worked well under all conditions, but that the gains from nitrogen fertilizers were more restricted. Nitrogen as "Nitro-chalk" increased heights only on plots which had also received limestone in 1949 and potassium fertilizer in 1949 and 1950. The benefits from the limestone were shown only on the plots which received nitrogen. These general results are illustrated in the following summary, Table 31.

ONE-YEAR SITKA SPRUCE, BAGLEY WOOD NURSERY, 1950

Table 31. Height in inches

	No Potassium No Limestone	Potassium	Limestone	Potassium & Limestone
No nitrogen	1.2	1.6	1.3	1.5
Nitrogen	1.0	1.5	1.5	2.4
Standard error	±0.10			

In a similar second-year experiment at Wareham, each of the square-yard plots was sown with six species to obtain some indication whether there were any marked differential responses between species. Sitka spruce gave the largest relative response to phosphorus fertilizer (the mean height per plot being increased from 0.9 to 2.3 inches) but the other species—Japanese larch, Douglas fir, Corsican pine, *Pinus contorta* and *Tsuga heterophylla*—all showed similar responses (around 70% increase in height). For all six species, nitrogen and potassium fertilizers each gave height increases of about one-third. These results indicate that the general conclusions drawn from the more detailed work on Sitka spruce may be applied with reasonable confidence to other common species.

The experiment revealed some odd details. Japanese larch, Douglas fir, Corsican pine and *Pinus contorta* showed marked benefits from residues of phosphorus fertilizer applied in 1949, but Sitka spruce and *Tsuga heterophylla* did not. The heights of *Pinus contorta, Tsuga heterophylla* and Sitka spruce were reduced by limestone residues on plots which received superphosphate in both seasons. No satisfactory explanation can be offered for these results. They are mentioned here mainly to illustrate some of the complexities which may be examined by factorial experiments when the plants grow well. In this experiment there was no residual benefit in 1950 from the potassium applied in a mixed fertilizer in 1949.

6. pH Range and Liming

Series of plots were established in the winter of 1947-8, at Wareham and Kennington Extension, to provide a wide range of pH values from 4.0 to 7.0. In 1950 most species tested as seedlings or transplants proved to be relatively insensitive to soil reaction. Sitka spruce and Norway spruce showed slightly better growth with small additions of limestone, both as seedlings and transplants, but poorer growth on heavily limed plots. In tests on seedlings at Wareham, *Tsuga heterophylla* grew badly at high pH values; Corsican pine, Scots pine and *Pinus contorta* gave somewhat poorer growth at high pH values; as in 1949, Aleppo pine (*Pinus halepensis*) turned yellow and failed on plots without added limestone. Somewhat unexpectedly, birch grew well over the whole range of soil reactions tested. It must remain for future work to show whether the 1950 results were anomalous, or whether the optimal pH ranges of most conifers are in fact wide and ill-determined.

7. Soil Acidification in Seedbeds

It was shown in 1945, the first year of these investigations, that growth of Sitka spruce in boxes could be greatly improved by previously acidifying soil obtained from Old Kennington Nursery. It was subsequently shown that in many of the established nurseries where Sitka spruce and other sensitive conifer seedlings grew badly, the soils were weakly acid or neutral. Many experiments have since been made to test various methods of removing surplus calcium from soils by acidifying agents. One of the main difficulties was to remove the soluble salts inevitably produced by acidifying treatments. Although the treatments were known to be dangerous, the plots were sown in the spring following acidification to measure the immediate risk. In the droughts of 1947 and in 1949 there were many examples of serious damage. In 1949 the acidification was done under more practical conditions on uncropped land to be sown in 1950. The results of three experiments in old established nurseries are shown in Table 32. All plots received NPK fertilizer for the 1950 crop.

EFFECT OF ACIDIFYING FALLOW SOIL IN 1949, ON ONE-YEAR SITKA SPRUCE SOWN IN 1950

Table 32

Nursery	Ringwood (R.4)	Ampthill (Am.3)	Old Kennington (K.26)
pH of untreated soil	5.6	6.4	7.5
Single rate of application, grammes per square yard			
Sulphur....	50	75	100
Ammonium sulphate....	100	150	200
	Height of Sitka spruce in inches		
Sulphur			
None....	1.5	1.6	1.2
Single Rate	2.0	2.3	1.6
Double Rate	2.5	2.7	2.0
Treble Rate	2.6	—	2.1
Ammonium sulphate			
None	1.5	1.6	1.2
Single Rate	2.2	2.3	1.7
Double Rate	2.5	2.6	2.3
Treble Rate	2.4	—	2.4
Standard Error	±0.10	±0.13	±0.10

In all three nurseries acidification by either sulphur or ammonium sulphate improved growth to an extent which increased with the degree of acidification. These three nurseries have been described in the past as "worn-out" or "Sitka-sick", but by suitable acidification the mean heights per plot reached around 2.5 inches in 1950. The experiments are being continued.

Several other experiments also showed good results in 1950 from acidification treatments given in the winter 1948-9. There were some experiments in which similar treatments in 1947-8 were ineffective, although, in the same experiment, those of 1948-9 gave good results. This illustrated a general problem which has been under attack for several years. Is the effect of drastic acidification relatively permanent, or is it essentially transient? In American nurseries seedbeds are often treated with small amounts of acidifying agents *after sowing*, presumably to obtain some temporary control of "damping-off". In most of our experiments we have been aiming at a more permanent effect, but it is by no means certain that we have secured it. Perhaps the best policy in practice would be to produce a big initial change, and then to continue with small annual treatments to maintain the acidification and secure each year the benefits of any transient local acidification. Experiments along these lines have been started.

One possible way of progressively acidifying soils would be to apply ammonium sulphate in a series of dressings throughout the growing season, in the hope that the cumulative benefit would be useful and the individual dressings safe. Such an experiment was started in Old Kennington Nursery in 1949. In that drought year, neither ammonium sulphate nor "Nitro-Chalk" (a substantially neutral material) had any effect. In 1950 ammonium sulphate plots carried good Sitka spruce, far better than those on plots which had received the same amount of nitrogen as "Nitro-Chalk". A very simple solution to the "established nursery problem" would be found if this result could be repeated elsewhere. The attempt is being made.

Comparisons of alternative acidifying agents have shown that the relative effects of ammonium sulphate and sulphur, though broadly similar, vary from place to place and year to year. Aluminium sulphate has hitherto proved less effective than either of the others when used in equivalent amounts.

8. Formalin and Steam for Seedbeds

In 1945, Mr. J. A. B. Macdonald obtained good results in the Edinburgh Royal Botanic Garden from treating the soil with dilute solutions of formalin in the manner commonly employed for the "partial sterilization" of greenhouse soils. We have obtained similar improvements in each year since then, in experiments in many nurseries. We have improved the technique of application and attempted to analyse the nature of the effects of formalin or steam, by varying the conditions and testing other materials believed to act more specifically as fungicides. There is still no satisfactory hypothesis on the way in which "partial sterilization" by steam and formalin acts on conifer seedlings. Many organisms, including some weeds, pests and pathogens, are destroyed but associated changes may greatly alter the nutritional conditions for the plant. The benefits from these "partial sterilizing" treatments are not restricted to soils on which conifer seedlings grow poorly, or to sites and seasons in which "damping-off" is serious. Very striking effects on growth have been obtained in experiments in which there was a full stand of poor plants on the untreated plots.

In an experiment with treatments applied early in 1949, at Ampthill nursery, steam and formalin gave good improvements in the first year Sitka spruce of 1949, and moderate residual effects on a second crop sown in 1950. Acidification shortly before sowing killed nearly all the plants in 1949, but the residual benefits from the acid on the 1950 crop were better than those from steam or formalin.

In a series of four experiments in three old-established nurseries the standard dressing, of about one pound commercial formalin (suitably diluted) per square yard, was compared with dressings of one-half and one-quarter of this amount. The gains from formalin treatments at all rates were particularly striking in Ringwood and Old Kennington nurseries. In all four experiments, heights increased with amounts of formalin in much the same way as plants commonly respond to increasing amounts of individual nutrients (See Table 33). In practice it might be economic to use less than the standard amount (1 lb. per square yard), hitherto tested. The application might be mechanized.

EFFECT OF FORMALIN ON ONE-YEAR SITKA SPRUCE, 1950

Table 33 Height in inches

Amount of formalin millilitres per square yard	Ringwood (R.29)	Kennington (K.43)	Ampthill (Am 7) (pH 5.3)	Ampthill (Am 8) (pH 6.4)
0	0.7	0.8	1.6	1.2
125	1.8	1.9	2.4	1.6
250	2.2	2.1	2.7	1.8
500	2.9	2.3	2.8	2.4
Standard error	±0.07	±0.05	±0.15	±0.10

Parallel experiments were made at six nurseries to test the effects and interactions of formalin, compost and inorganic fertilizers. The series included two nurseries with very acid soils, the heathland of Wareham and the conifer forest clearing of Bagley Wood. Where no formalin was given, neither fertilizer nor compost gave good plants on the three established nurseries—Ringwood, Ampthill and Old Kennington. Formalin improved growth at all nurseries under all manurial conditions, except on plots receiving fertilizers but not compost on the two very acid soils (Bagley Wood and Wareham). The gains from formalin were outstanding at all nurseries on plots which had received compost. Where compost and fertilizers were used together, formalin increased mean heights by about one inch at all six nurseries. Where compost was used alone, the increases were more irregular, ranging from 0.6 to 1.5 inches. In the established nurseries, plots with compost fertilizer and formalin gave plants as big as those grown with compost alone at the two very acid nurseries.

No adequate explanations can be given for all of the differences revealed in these experiments. The formalin was applied immediately after forking in the compost, phosphate and potash. The nitrogen fertilizer was applied a few weeks later, shortly before sowing, and the dressing was repeated in midsummer. It is possible that the formalin slowed down the liberation of available nitrogen from the compost, whereas ammonia or nitrate from the fertilizer was lost by leaching during the wet autumn. In several of the nurseries the plots with formalin, compost and fertilizer together stood out not only in their size (around 5.0 inches at Bagley Wood and Wareham) but in their rich blue-green colours—an unusual condition in the autumn of 1950.

A more detailed examination of the interplay between formalin and plant nutrients was made in a series of three experiments at Kennington Extension, Ringwood and Old Kennington. The interactions were so involved that it is necessary to give means of sets of eight treatments to show the significant results.

INTERACTION OF FORMALIN AND NUTRIENTS

One-Year Sitka spruce sown 1950

Table 34 Height in Inches

	Kennington Extension (KE.50) Without formalin	Kennington Extension (KE.50) With formalin	Ringwood (R.33) Without formalin	Ringwood (R.33) With formalin	Old Kennington (K.44) Without formalin	Old Kennington (K.44) With formalin
No N. no P.	1.6	2.5	0.4	0.7	0.6	1.7
N alone	1.9	1.9	0.5	0.7	1.0	1.3
P alone	1.6	2.8	0.3	1.0	0.7	2.0
N + P	2.0	3.3	0.6	1.6	0.9	2.3
Standard error....	±0.13		±0.05		±0.11	

At all three nurseries, nitrogen and phosphate fertilizer had only small effects on plots without formalin. At all three, formalin had small effects on plots receiving nitrogen but not phosphorus, but formalin had relatively large effects on plots receiving phosphorus without nitrogen, and very large effects on plots receiving both nitrogen and phosphorus.

On plots receiving formalin, at all three nurseries, nitrogen reduced heights where no phosphorus was given, but markedly increased heights where phosphorus was given.

Interactions as complex as the ones just discussed are likely to depend on seasonal conditions, and it may be better to postpone any attempt to interpret them until comparable data have been obtained in other years. Even at this stage, the experiments suggest that the action of formalin may involve nutritional effects, probably affecting the rate and form of root growth. In the present state of our knowledge, there is little to be gained by using the term "partial sterilisation" to "explain" observed effects, or to imply any hypothesis about mechanisms. The term "partial sterilisation" does little more than summarize the statement that drastic treatments destroying many kinds of soil organisms often increase the growth of subsequent crops. The conditions under which various methods can usefully be employed in practice, can be ascertained only by much detailed experimental work in the field and laboratory.

In current investigations, considerable attention is being given to the hypothesis that in conifer seedbeds an important factor in the effects of steam, formalin, and other treatments is to produce and maintain a higher concentration of ammonia in soils that can be achieved without these materials.

The plants raised with formalin in established nurseries are being tested for subsequent performance in transplant lines and in forest plantings. It is generally impossible to make extension experiments on this question, because the plants raised on untreated plots in the established nurseries are generally too small to handle in this way. The preliminary data so far available indicate that plants raised with formalin on old-established nurseries behave as well in the forest as those from several of the younger research nurseries with acid soils, but not as well as those from Wareham.

9. Fungicides for Seedbeds

Experiments were made at Old Kennington and Ampthill nurseries, and on soils from these nurseries in pots at Rothamsted, to test a number of fungicides as possible alternatives to steam and formalin. If one of the main effects of "partial sterilization" was to destroy pathogenic fungi, it might be expected that a suitable fungicide would have similar effects. None of the fungicides tested gave benefits at all approaching those from steam and formalin, though several of them reduced losses through "damping-off" in the pot experiments. Several of the fungicides seriously reduced plant numbers. The materials tested included an organic mercurial, calomel, copper-8-quinolinolate, iron dimethyldithiocarbamate, tetrachlor-nitrobenzene, thiuram, bleaching powder, hexamine, cuprammonium, cuprous oxide, potassium permanganate, and two antibiotics (gliotoxin and frequentin). In a year with good growth in pots or on plots treated with steam or formalin, the failure of fungicides incorporated in the soil, applied as seed-dressings or after sowing, is fairly strong presumptive evidence that "partial sterilization" involves something beyond the destruction of soil fungi.

The progressive changes in the soils of the Ampthill experimental plots on steam, formalin and acid treatments were followed throughout 1949 and 1950 by Miss L. M. Crump and other members of the Rothamsted Microbiology Department, and by Mr. R. G. Warren of the Chemistry Department.

10. Transplant Manuring

Experiments on the manuring of transplants were continued for the third season at Wareham Nursery, Dorset, at Reasty Top (Broxa, Langdale Forest, Yorks.) on a heathland soil and at Rosedale Banks, Rosedale Forest, Yorks., on a neutral established nursery. At Wareham there were large improvements from nitrogen and potassium fertilizers with small benefits from phosphorus; at Reasty Top good responses to phosphorus and potassium fertilizers but only small ones to nitrogen; at Rosedale Banks very large responses to nitrogen and phosphorus fertilizers. In general, there were only small differences between ammonium sulphate, "Nitro-Chalk" and crushed hoof. Naturally the continued use of ammonium sulphate on very acid soil would not be recommended in practice. It has been employed in the experiments only to assess the risk of damage under extreme conditions.

11. Extensions, to the Transplant Stage, of Experiments in Seedbeds

Differences due to nursery treatments remained small in the transplants of 1950 in most experiments, but there were a few in which the treatment differences increased in the transplants. These included experiments in Old Kennington and Ampthill Nurseries, in which transplants from seedbeds with formalin in 1949 gained on those without. At Reasty Top and Rosedale Banks, plants which had received nitrogen fertilizers at the seedling stage grew better, as transplants, than those grown without nitrogenous fertilizers in 1949. It appears from these experiments that nitrogen absorbed by the seedlings late in 1949 was unable to lead, in that season, to proportionate growth, but helped growth the following season in the transplant beds. Observations of this kind may be of practical value for, hitherto, there has been very little evidence of the extent to which proper manuring in the nursery can improve the subsequent performance of the plants elsewhere.

12. Forest Experiments

Assessment data at the end of 1950 have been analysed for plantings early in 1947 and 1949. On a very acid heathland at Broxa, Langdale Forest, in North Yorkshire, one-plus-one Sitka spruce and Scots pine, planted early in 1947, grew very well, and showed large responses to phosphorus fertilizers and smaller ones to nitrogen and potassium fertilizers. In Sitka spruce, full manuring increased mean heights from twenty-one to forty-two inches. In a parallel experiment at Dartmoor Forest, Devon, there were good responses of Sitka spruce to nitrogen and phosphorus fertilizers, but not to potassium fertilizers; effects on Scots pine, from similar treatments, were negligible.

In extension experiments (from nursery to forest) planted early in 1947, Sitka spruce at Broxa grew almost as well as at Dartmoor. The one-year seedlings reached nearly the same height as the one-plus-one transplants at Broxa, but not at Dartmoor.

In 1947 plantings on a very poor site at Decoy Heath, Wareham, all experimental rows received phosphate fertilizer. By 1950, early differences due to nursery treatment and to nitrogen and potassium fertilizers in the forest had become very small. The Sitka spruce have now gone into check, but the Scots pine continue to grow well and to show a small benefit from nitrogen fertilizer given in 1947.

Early in 1949, seedlings and transplants from experiments in six nurseries were planted out as extension experiments in four forests, two for Sitka spruce and Scots pine together and two for the separate species. The experiments were arranged in blocks, which were used to test the effects of inorganic NPK fertilizer applied as two pellets, each of 28 grammes, placed about six inches from the trees.

At Broxa the fertilizers had a marked effect on vigour in the year of planting, and on heights at the end of the second year. The heights of the Sitka spruce trees planted as one-year seedlings were almost doubled by fertilizer and reached the same heights as on the good soil of St. Gwynno Forest, Glamorgan. The gain from fertilizer was much less at Kerry Forest, Montgomeryshire. Fertilizers had no effect on the Sitka spruce at St. Gwynno and gave a small but consistent reduction in heights of Scots pine at the King's Forest, Suffolk. This may have been due to increased competition with grass. Other experiments showed that the action of the NPK fertilizer was due mainly to the phosphorus supplied. (Table 35.)

EFFECT OF FERTILIZER APPLICATIONS ON TWO SEASONS' GROWTH OF SITKA SPRUCE AND SCOTS PINE AT THREE FORESTS

Table 35 F—Fertilizer at planting Mean Height in inches

Treatment	Assessments late 1950 for plantings early in 1949					
	Broxa		Kerry Hill		St. Gwynno	
	No F	F	No F	F	No F	F
Sitka spruce planted as:						
One-year seedling	8.2	15.2	6.8	8.1	13.5	13.6
One-plus-one transplant	14.8	21.2	14.2	16.0	21.4	21.2
Scots pine planted as:					King's Forest	
One-year seedling	7.8	10.2	6.3	6.8	11.3	10.5
One-plus-one transplant	14.8	15.9	11.7	12.2	18.0	17.5

13. Survival of Seedlings Planted Directly in the Forest

First-year seedlings of Sitka spruce and Scots pine, planted in three forests in 1947, survived well; but there have since been a number of failures from plantings in later years. The 1947 plantings were done in specially prepared planting patches. The later plantings, except at Broxa, were deliberately made by local Conservancy methods to provide strictly practical conditions. The losses were severe on some of the grassy sites, and for plantings on the top of ridges or slices thrown up by deep ploughing at high elevations where frost lift or surface wash may have been serious.

Losses were particularly bad in the Welsh forests during the wet winter of 1950-1 for plantings done early in 1950, the smaller plants being washed away with the top few inches of loose friable soil. General observations, as distinct from experimental tests, suggest that there were marked differences in survival according to the nursery of origin, seedlings from Wareham and Wytham nurseries being markedly better than those from Bagley Wood or Kennington Extension nurseries.

In recent years a large proportion of the forest planting experiments, both on extensions and manuring, have been made on rather small one-year seedlings. It now appears that only the larger seedlings are suitable for current planting methods. One-plus-one transplants from all nurseries have survived well in the forests. In the future it may be better to give more attention to the production and testing of transplants, especially the large ones produced by manuring heathland nurseries and those obtained experimentally in established nurseries of poor performance. Good results have been obtained in several of these nurseries in raising seedlings, and some of the methods employed for seedbeds also offer promise for transplant beds.

RESEARCHES IN SOIL MYCOLOGY

By Dr. IDA LEVISOHN
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Effect of Surface Mulch on Root Infection

The striking changes brought about by mulching on shoot development and colour of foliage in checked spruces, Lawson cypress and other tree species, is accompanied by a pronounced effect on root growth and root infection. The beneficial influence on both shoot and root condition is already obvious after the first growing season.

Root material from a number of planting experiments at Wareham Forest, Dorset, was examined at various seasons and showed great increase in long- and short-root formation where an organic surface mulch (bracken or heather) was applied. Simultaneously, root infection was increased.

Norway Spruce

The changes produced by a mulch are most pronounced in Norway spruce which, in the Wareham soil, has been found to be even more refractive than Sitka spruce. Observations extending over many years have shown that check to shoot growth and severe chlorosis of the foliage are associated with arrest of root development, and either absence or remarkable scarcity of mycorrhiza-formation, irrespective whether the trees grow in a wet or dry part of the area. The symptoms of check are not appreciably relieved by application of phosphate. They are, however, rapidly removed by mulching. Chlorosis disappears, the foliage becomes bluish-green; shoot growth improves. At the same time, incidence and (or) type of root infection undergo a remarkable change. The following examples serve to demonstrate the effect of a surface-mulch on root infection in Norway spruce.

Experiment 61, 1942. (*Decoy Heath*):—Heather mulch used. Origin of plants R.8, P.38, the field plot where soil from a Swedish stand was introduced. This soil inoculum contained a mycelium which facilitated mycorrhizal development but the beneficial action was more than counter-balanced by simultaneous introduction into the field plot of a pseudomycorrhiza-former, *Mycelium radicis atrovirens* (beta), comparatively inocuous to the welfare of the trees under native conditions, but found to be deleterious when brought into the new environment provided by the soil of the experimental area at Wareham Forest. The plants went into severe check.

In the planting experiment 61, 1942, where Norway spruce from this field plot was introduced, the unmulched plants remain in check. Their root systems are extremely poor, showing a pronounced deficiency in short-root growth. The roots are heavily attacked by a pseudo-mycorrhiza-former which produces large sclerotia. The mycelium was isolated and identified as *Mycelium radicis atrovirens* (beta).

The mulched plants have improved considerably, in particular as regards colour, and carry well-developed monopodially branched root systems characteristic for healthy Norway spruce. The roots are fully mycorrhizal and do not show any pseudomycorrhizal attacks.

It appears that by favouring mycorrhizal development, the mulch protects the root system from deleterious infections.

In a number of other planting experiments with Norway spruce, i.e. Expt. 76, 1945 (Bere Heath), heather mulch has also brought about free development of normal mycorrhizas, while the checked unmulched plants exhibit a considerably reduced and non-mycorrhizal root system.

The effect of a surface bracken mulch is demonstrated in Expt. 87, 1948 (Decoy Heath), a randomized planting experiment for which pseudomycorrhizal seedlings were used. Though this experiment suffered from setbacks, i.e. severe frost, the effect of the mulch on colour of the foliage and on root conditions is most obvious.

The unmulched chlorotic plants show poor root development, with some pseudomycorrhizal infection carried over from their nursery of origin. The mulched plants, which exhibit a bluish-green colour, bear monopodially branched roots which are fully mycorrhizal. No trace of a pseudomycorrhizal infection has been observed. Obviously, the mulching has stimulated the activity of the mycorrhiza-former present in the soil of the experimental area.

Sitka spruce

In all experiments examined, i.e., Expt. 76, 1945 (Bere Heath), heather mulch has brought about full development of mycorrhizal infection while the checked unmulched plants are non-mycorrhizal.

Lawson cypress

In Expt. 29 P.37 (Sugar Hill), a heather mulch has greatly stimulated the endotrophic mycorrhizal infection. The checked unmulched trees show very severe attacks by a *Rhizoctonia* species, apparently carried over from the nursery from which the plants were imported.

Other species

In birch, mycorrhiza-formation was found to be remarkably encouraged by application of a heather mulch. At Sugar Hill, a bracken mulch has affected the endotrophic mycorrhizas of alder buckthorn. The checked (unmulched) trees have no normal root associations but show a subnormal type of endotrophic mycorrhizal infection. Mulching has "corrected" the deviation from the normal type, and has produced a rich development of healthy mycorrhizas.

Pre-Mulching. In order to determine how mulching the soil, before planting, might affect the soil fungi, in particular mycorrhizal mycelia, an experiment was laid down at Sugar Hill (W.9, 1950) in simple randomized blocks, using organic (bracken) mulch compared with inert (acetylated cellulose) mulch, both on composted and non-composted plots.

Analysis of soil from this experiment shows that the application of bracken mulch raises the percentage of available potash from .001 to .015. The inert mulch has not produced any effect on the potash content.

The experimental blocks have now been sown with a number of selected species, and height and out-turn assessments will be carried out at the end of 1951. Examination of soil and root mycelia are in progress.

Haustorial (pseudomycorrhizal) Infection in Pine

In old-established nurseries of the agricultural type, the roots of *Pinus* spp. show a characteristic intra-cellular infection which appears to be directly connected with the particular soil conditions.

Though spruces reflect the "poor" soil conditions more delicately in their growth reaction and simultaneously as regards root infection, pines were chosen as test plants in most of the large-scale pot-experiments for the following reasons: The pseudomycorrhizal associations of pines growing in soil from old-established nurseries are produced by hyphae forming an intra-cellular invasion of the cortical tissues. It is a type of infection not difficult to diagnose and establishes itself in an early stage of seedling development. In spruce, however, the pseudomycorrhizal infection promoted in such nursery soils is not so easily recognized, and, for laboratory work, has the disadvantage that, in general, it develops considerably later than in pine.

So far, the results obtained from field work, pot-cultures and laboratory experiments can be summarized as follows:—

1. Haustorial infection is characteristic for pines growing in old-established nurseries of the agricultural type.
2. Mycelia causing this form of pseudomycorrhizal infection have been isolated and are available in pure culture.
3. Though haustorial mycelia have not been found to be endemic in soils of the heathland type, they are easily introduced into these soils by minute soil inocula or fragments of root material containing haustorial myeclia. pH is not a limiting factor to the formation of haustorial association by mycelia brought in by soil or root inocula.

   Introduced into soils of identical pH value, the haustorial mycelia cause heavy pseudomycorrhizal infection only in those soils that are relatively poor in microbial activity, while "richer" soils greatly inhibit the establishment of such pseudomycorrhizas.

   In sand-cultures, minute soil inocula containing a haustorial fungus produce root systems which are fully pseudomycorrhizal, of the intra-cellular type.
4. Haustorial mycelia vary considerably as regards their virulence. The infections which they bring about can be directly harmful, by inducing chlorosis of the foliage, but without always having a pronounced adverse effect on shoot development. They can be rather harmless insofar as they may not damage the plant directly. By preventing the formation of true mycorrhizas, however, they are all the same definitely undesirable.
5. It appears that haustorial infection occurs in such soils (and other media) in which a suitable mycorrhiza-former is either absent or where its activity is inhibited.
6. So far, no proof has been established—though some facts are very suggestive—that, under natural conditions it is possible to convert mycelia which are normally mycorrhiza-formers into the role of pseudo-mycorrhiza-formers.

Toxicity in Wareham Soil

The opinion has been held that in some of the areas at Wareham Forest a high water content of the soil, accompanied by poor aeration, is responsible for promoting conditions favourable for the production of toxic substances. In fact, high toxicity has always been observed to coincide with seasons in which water-logging is very pronounced, while during the dry seasons toxicity was low.

It was therefore expected to find a high degree of toxicity induced by the extreme wet conditions of winter and spring 1950-51. Samples from a selected area at Decoy Heath, where toxic conditions used to be most obvious, were repeatedly examined by the nutrient-agar-film test method. There was no indication of toxicity in any of these samples collected from various depths. This phenomenon of "disappearing" toxicity deserves further investigation.

It is suggested that either the toxic substances have been thoroughly washed out by the excess of rain, or that ecological changes which may have occurred are causing the different behaviour of the soil. Most likely it is the latter factor which is responsible for this change, as an improvement of the soil in question has been observed in recent pot-cultures, in which pine and spruce seedlings exhibited a definitely better growth, and a more normal root infection, than in earlier years.

Infection and Re-infection of Roots in Partially Sterilized Soil

The effect of partial sterilization of a degraded nursery soil (Ampthill, Beds.) was studied in pot-cultures using oak, sweet chestnut, Sitka spruce and Scots pine as test plants. There is no indication that the presence or absence of certain root associations plays a part in producing the beneficial "sterilizing" effect on seedling growth and vigour.

INFLUENCE OF TREE GROWTH ON SOIL PROFILE DEVELOPMENT

By T. W. WRIGHT
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The writer was appointed in succession to Dr. J. D. Ovington on 1st September, 1950, with the object of continuing the latter's investigations into the influence of tree growth on soil profile development.

Culbin Forest, on the north coast of Morayshire, was again chosen as the main area for investigation, so that results could be correlated with Dr. Ovington's work, which was published recently (Ovington, J. D., 1950. The Afforestation of the Culbin Sands. *Journal of Ecology* 38(2), 303). A visit was also made with Mr. J. A. B. MacDonald, Silviculturist (North), to the Norway spruce sample plots at Bowmont Forest, Roxburghshire, where the appearance of a typically nitrophilous vegetation, in the plots thinned on D and Low Crown grades, had been observed. Further work at Bowmont was postponed until the summer of 1951, when the differences in ground vegetation and microbiological activity would be most apparent.

Establishment of Sample Plots

At Culbin, sample plots for soil studies were re-established on a bare sand dune, and in compartments bearing ten- and twenty-year-old Corsican pine growing on comparable sites. New sample plots were established on similar sites bearing respectively forty-seven year old Corsican pine, eighty-year old Scots pine, birch, a dry *Calluna* heath vegetation, and on a newly-thatched dune which has not yet been planted. It was thus hoped to extend Dr. Ovington's investigations, which had been confined to bare dunes and Corsican pine up to twenty years old, to include soils both under older trees and under different types of vegetation, and to assess the contribution of the thatching towards sand stabilization and soil development. Profiles were dug in all sample plots to a depth of five feet, and samples removed for chemical and mechanical analysis.

Development of Field and Laboratory Methods

Field Methods

On the high sand dunes of Culbin Forest, moisture is one of the most important factors limiting tree growth, and the investigation of the influence of tree growth on the moisture status of the sand forms a major part of the work in this area. A number of Bouyoucos gypsum moisture blocks were constructed and buried at depths of 3 inches, 9 inches, 1 foot 6 inches, 3 feet, and 5 feet, in each of the sample plots. Delay was experienced in obtaining a portable alternating current bridge suitable for measuring the resistance of the blocks, but it was hoped to start taking readings in the summer of 1951.

Several thermistors were also purchased, for use as small electrical resistance thermometers, for measuring soil and air temperatures and air humidities in the sample plots. Calibration and installation of these also awaits the arrival of the bridge.

Laboratory Methods

(*a*) *Chemical Analysis.* Colorimetric methods for the determination of iron and aluminium in soils, developed at the Macaulay Institute, were adapted for use in estimating the total iron and aluminium in the sample plot profiles, and hence obtaining an index of the intensity of podsolization which had taken place under the various types of vegetation.

(*b*) *Methods of Assessing Microbiological Activity.* In collaboration with Dr. Lees, of the Department of Biological Chemistry, University of Aberdeen, who very kindly lent six percolation units and gave advice on their operation, a battery of Lees percolators was set up, with a view to studying nitrite and nitrate production of samples from both Culbin and Bowmont forests, when percolated with dilute ammonium sulphate solution, and using this as a guide to the microbiological status of the respective soils.

MINERAL NUTRIENT STUDIES IN HEATHLAND PLANTATIONS

By Dr. L. LEYTON
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Investigations continue into the mineral nutrient status of spruce and pine planted in *Calluna*-dominated heathlands. Removal of the heather, and fertilizing with graded amounts of rock phosphate, was carried out in June, 1949, in a mixed plantation of Sitka spruce and Scots pine in Clashindarroch Forest, Aberdeenshire, and of Sitka spruce and Corsican pine at Wykeham, Allerston Forest, Yorkshire. At the end of the growing seasons of 1949 and 1950, assessments were made on the growth of the trees (including needle dry weights in 1950) and at the same time samples of the current year's needles taken for analysis. The following results have been obtained:—

Effect of Phosphorus Fertilizing

Sitka spruce

By the end of 1949, the needles of the trees in both areas showed an increase in phosphorus content (percentage dry weight) with increasing applications, up to two ounces per tree. Beyond this there was no significant change in the phosphorus status. Similar results were obtained in the 1950 samples. No corresponding changes have so far been observed in the growth response of the trees, except for a slight increase in needle dry weight in Yorkshire.

Pine

No significant response on either nutrient status or growth.

Effect of Removal of Heather, Calluna vulgaris

Sitka spruce

By the end of 1949, significant changes were observed in needle composition. In both areas screefing resulted in a marked increase in the amount of potassium, and a decrease in the amounts of calcium and manganese taken up by the needles. No change was observed in the nitrogen status of the trees, nor was there any obvious growth response apart from a suspected increase in the average needle dry weight of the spruce at Wykeham.

By 1950 the trees on the screefed plots, particularly at Wykeham, were showing a marked improvement in colour, contrasting strongly with the chlorotic appearance of the trees on the unscreefed plots. Corresponding with this, there was found a significant increase in the nitrogen status (1.3 to 1.8%) and a marked increase in the dry weight of the needles (2.6 to 4.0 milligrams per needle) making the absolute nitrogen content of the trees on the screefed plots about double that on the unscreefed plots. A smaller but still significant increase in nitrogen content was also observed at Clashindarroch, but there has been no such marked change in the needle dry weights. As yet, no figures are available for the other mineral nutrients.

Pine

No significant changes in needle composition or growth in 1949. In 1950 the Corsican pine at Wykeham revealed a significant increase in nitrogen status, together with an increase in needle dry weight. No such changes have been observed with the Scots pine at Clashindarroch.

The above findings confirm earlier suggestions that chlorosis and checking of Sitka spruce in the presence of *Calluna* must be attributed primarily to a nitrogen deficiency. How this is brought about is not yet established. A marked positive correlation observed between the nitrogen status of the spruce and the *Calluna* plants found in the vicinity, might be interpreted in terms of severe competition for the limited amount of nitrogen available in these soils; but it is also possible that the removal of the *Calluna* results in an increased availability of nitrogen, e.g. by decomposition of dead *Calluna* roots. Phosphate applications, despite increasing the phosphorus status of the needles of the spruce, have so far resulted in no marked growth responses, except perhaps the suggested needle dry weight increase at Wykeham. The significance of the changes in potassium, calcium, and manganese status with removal of the *Calluna* is not yet fully understood, but undoubtedly antagonism between potassium and calcium must be considered.

Further investigations on a plot of Sitka spruce at Clashindarroch, mulched with heather, which resulted in a significant improvement in the vigour of the trees, revealed a corresponding increase in the nitrogen status of the needles. Studies have also been made on checked spruce at Broxa, Langdale Forest, Yorkshire, treated with various nitrogen and phosphorus fertilizers, singly and in combination. The results for the phosphorus fertilizers are not yet available, but as might be expected, the nitrogen fertilizers have resulted in a significant increase in the nitrogen status of the trees.

There appears to be a marked relationship between the nitrogen status of the spruce needles, the average dry weight of the needles and the growth of the trees. Since the more vigorous trees invariably possess heavier needles, the fact that changes in needle dry weight have been observed before changes in height or volume growth of the trees, may be of importance in assessing the effects of various silvicultural treatments on tree growth.

Nutrient Status of Calluna as an Indicator of Site Quality

The marked correlation between the nitrogen status of *Calluna* and spruce growing in the same vicinity, and the relation between the nitrogen status of the spruce and its growth, suggested the use of *Calluna* as an indicator of site quality. Previous investigations (see 1950 *Report**) showed that the nitrogen status of *Calluna* varied significantly in different areas and in different communities. These investigations have been continued by Mr. J. R. Aaron, with a view to confirming the earlier findings and to establishing whether seasonal variations would materially affect the results. Analyses have been carried out on *Calluna* sampled at different times of the year from various communities at Greenham, Newbury, Berkshire. Despite variations in the nitrogen status of the plants with the time of the year (especially during the flowering stages) the differences between communities were maintained. *Calluna* growing with *Pteridium* (bracken) was consistently higher in nitrogen status than *Calluna* of the same age growing with *Juncus* (rush) or *Ulex* (gorse), and all these are invariably higher than in nearly pure *Calluna*, with *Erica tetralix* (cross-leaved heath) as sub-dominant. It appears that the nitrogen status is related to the luxuriance of the *Calluna* growth, which has often been used as a guide to site fertility.

RESEARCH INTO THE PHYSICAL AND CHEMICAL PROPERTIES OF FOREST SOILS

By P. J. RENNIE

Imperial Forestry Institute, Oxford

The success of new field apparatus described in earlier reports, and the improved laboratory facilities at Oxford, have made possible a great amount of work in the past year; all told some 500 soil profiles have been dealt with, and clearly this short abstract cannot even touch on all the lines of progress. Mention will only be made, therefore, of some of the more important conclusions in the physical field.

Studies of particle size distribution in a range of soils from the Allerston Forest area in Yorkshire have shown that an increase in the smaller particle sizes is usually correlated with increased difficulty of afforestation in these soils. The coarse sand of the Passage Beds is easier to deal with than the fine sand of the Lower Calcareous Grit, which has also a higher clay and silt content. The success of cultivation techniques also appears to be related to the particle analysis. Where there are local patches of higher clay content, as on Silpho Moor, shallow ploughing of these results in greater mortality and poor growth, whilst deep ploughing has the opposite effect, in comparison with survival on sites with less clay.

Porosity has been studied in great detail, and it is only possible to mention one or two of the more obvious, but not necessarily the most important, practical conclusions. Deep ploughing hardly alters the porosity under the ridges, so that, on normal (four feet six inches between ridges) ploughing, some 38% of the land is left with its original poor aeration. The aeration of the inverted and undisturbed peat horizons, however, is greatly increased, and on the lighter soils this can result in much improved humus conditions. The effect of trees on porosity has been the subject of a number of comparative tests. It is noteworthy that, even with shallow ploughing, aeration under twenty-year-old Sitka spruce is improved down to 60 centimetres (about two feet) depth throughout the year. This demonstrable improvement in

* *Report on Forest Research* 1950. H.M.S.O. 3s. 6d. Page 118.

aeration as the result of tree growth is a factor of first importance, and it would be unwise to endanger it by exposing the soil at any time to the compacting action of rainfall on an unvegetated surface.

The rooting habits of both tree and moorland species have been studied, with interesting results. The fact that *Calluna* roots can reach below the pan, presumably through small fissures, suggests that tree roots might be able to follow; on some sites, indeed, Scots pine can do so, whilst in places Sitka spruce can be surprisingly deep rooting.

A great deal of work has been put into ascertaining the history of many sites over the past century or two, and this is more than rewarded by the explanations provided for apparently anomalous differences of growth and vegetation in many parts of the forest.

SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY
Imperial Forestry Institute, Oxford

During the past year soil faunal investigations have been concerned with a continuation of identification and assessment of samples, to complete the projects outlined in earlier reports. In this sphere, the soil faunal survey of natural and afforested heathland has occupied a considerable portion of the time. Much time has also been devoted to a biological study of certain members of the soil *Acari*, and whilst most of this work is exploratory in nature, some interesting facts have been revealed, together with indications of fruitful lines of investigation for the future. These experiments have clearly shown the limitations of present methods, and though in the absence of convenient alternatives, they must still be used, it is likely that a reorientation of approach will be necessary before real advances can be made.

Improvements in extraction technique have revealed staggering population numbers in natural heathland. These are even more striking when it is remembered that results with present methods frequently fall far short of the actual population total. Knowledge of this biomass and its activity, and its application to the harnessing of this potential to man's agricultural and forestry needs, may prove a far greater advance than is at present realised.

In the writer's opinion, it is not possible to apply directly the present modicum of knowledge of the soil fauna in devising practical measures to assist in forestry operations, one of the obvious reasons being the lack of knowledge of the habits of these creatures, and worse still the paucity of information concerning the magnitude and nature of populations occurring under different conditions; for example there had been no survey of soil organisms of forest areas in this country prior to the commencement of these investigations. Although the immediate application of measures in this sphere is not feasible, there are obvious indications of its potentialities, especially in the use of these creatures as indicators of particular conditions, in the short term view of particular edaphic conditions (an interesting example of which will be quoted later) and the longer term possibility of using soil populations together with other criteria as indices of the attributes of forest soils.

Population Survey in the Allerston Forest area, Yorkshire

The work of identification and assessment of the sample material has proceeded steadily, but much remains to be done before a clear qualitative picture of the fauna can be established. It has however reached a stage where certain quantitative features are manifest. These populations (Table 36), partly as a result of modified extraction technique, indicate remarkably large numbers of organisms in the undisturbed heathland, and are believed to be the largest recorded in this country.

TOTAL POPULATION OF SOIL ARTHROPODA IN HEATHLAND AND OTHER HABITATS

Table 36

Habitat	Sample depth in inches	Numbers per sample	Numbers per acre in MILLIONS	Numbers per cubic centimetre	Sample volume in cubic centimetres
NATURAL HEATHLAND .... (maximum)	3¼	860	1,987	5.95	144.62
HEATHLAND WITH TREES .... (maximum)	14	1,143	2,640	1.83	622.96
GRASSLAND[1]	12	2,756	1,378	1.15	2,471
ARABLE LAND[2]	9	201	105	0.11	1,770

1. Salt, G. et al. (1948)
2. Baweja, K.D. (1939)

In Table 36 these figures are compared with the most recent figures for grass and arable land; it is not possible to compare them with other forest habitats, owing to the absence of surveys of areas of this type. The numbers per acre have little real value, but have been included for comparison, as, in the past, in surveys of this nature, it has been customary to indicate populations in terms of this area. It should be stressed that although the number of units of living matter appear markedly more numerous than in grassland, the biomass, if it were possible to measure this characteristic, would greatly favour the latter. This is an aspect of population survey which must be considered sooner or later. Despite these large totals, under certain conditions, they may be gross underestimates of the true population density. Forsslund (1947) has examined directly small samples from Swedish forest sites and has obtained a population of 2,300,000 individuals per square metre. Whilst it would be unwise to regard this as a true estimate, owing to the methods used in sample selection, etc., even a fraction of this total, e.g., 50 per cent., shows a twofold increase when compared with the maximum population in Table 36. A further point of interest is the considerable population compression in the heathland (clearly shown in the population/volume figures). Deep sampling has yielded very few organisms below the raw humus layers.

Samples from the cultivated and planted heathland have been obtained from experimental plots planted with Sitka spruce now about twenty years old. In the better plots the trees have reached canopy. Deep samples from these sites show some interesting features. There is an increase in numbers and biomass, partly due to the litter layer on the surface, although about 50 per cent. of the population occurs in the raw humus "sandwich" formed during the "ploughing" process. In addition, more organisms occur in the mineral soil, especially in the layer above the humus "sandwich". Frequently the buried humus contains large numbers of dead mites; this may be due to a reduction in numbers immediately after ploughing, and/or increased activity with its resultant residue of animal remains. This aspect requires further investigation, but is unfortunately a lengthy process owing to the crumbly nature of the raw humus, which makes assessment very difficult.

One further aspect of the deep samples from the natural heathland is worthy of notice. As already stated, the number of organisms present in the mineral soil below the raw humus horizon is extremely small. Apart from a few *Collembola*, only one species of mite has been found. The latter belongs to the *Acaridiae*, a group which includes the cheese mites. These mites, unlike the *Oribatei*, can live under conditions of low oxygen and/or high carbon dioxide concentrations. There is thus a suggestion that of the four factors: living space, food, water and oxygen, the last-named is the dominant attribute controlling the volume of soil inhabited by these creatures, and here responsible for a large volume of mineral soil being almost devoid of organisms of this type. Dr. A. M. Hughes, of the Royal Free Hospital School of Medicine, has provisionally identified this mite as a new species of the genus *Schwiebia*, and it is intended to publish a joint paper on its taxonomy and ecology in the near future.

In last year's report, the writer drew attention to populations occurring in the birch litter experiment at Broxa, where there were indications of a very active surface and subsurface fauna in the plots where birch litter had been applied. Table 37 gives an indication of the major groups of organisms present. Points of interest are the larger numbers of *Collembola*, and the occurrence of *Enchytraeid* worms in some samples. Owing to the small number of samples taken, these must be regarded merely as possible trends.

NUMBERS AND KINDS OF ORGANISMS IN BIRCH LITTER PLOTS, EXPERIMENT NO. 51. BROXA, LANGDALE FOREST

Table 37

Sample type	Acari	Collembola	Enchytraeidae	Others	Total	Extraction dried sample weight, grams	Numbers per gram
BIRCH LITTER No. 1....	618	91	—	10	719	25.08	28.7
BIRCH LITTER No. 2....	435	11	—	5	451	12.56	35.1
BIRCH LITTER + SCREEFING No. 1*	94	37	8	5	144	50.28	2.7
Ditto No. 2*	14	16	7	4	41	84.33	0.5
HEATHLAND No. 1	595	21	—	2	618	22.07	28.0
HEATHLAND No. 2	795	35	—	7	837	21.95	38.1

* Total populations of these samples unreliable because of poor condition due to screefing treatment.

BIOLOGICAL STUDIES

Investigations into the biology of soil Acari have continued. Further improvements have been made in culture methods, and a culture technique devised which has proved reasonably successful. Mr. J. A. Spencer carried out an investigation into the food habits of certain species under the writer's supervision. The results of this work provide some interesting pointers for future investigations. Briefly this study consisted in the culturing of three species of *Acari*, *Hoploderma magnum* Nic., *Hermannia gibba* C. L. Koch, *Tectocepheus velatus* Mich., on various tree litters for a period of five months, with the following objects in view:—

(*a*) The suitability of the culture method.
(*b*) Food habits and litter preferences of the three species.
(*c*) The amount of litter consumed in culture.

Ash, birch, Douglas fir and Scots pine litters were chosen, as examples of broadleaf and conifer species having reputations for rapid and slow decomposition respectively. The results may be summarized as follows:—

(*a*) Of the species chosen, *Hoploderma magnum* proved a very successful subject for culture. The second species was rather variable in its reaction, whilst with the third there were no obvious signs of feeding or excrement during the period of the experiment, and its mortality rate was very high, especially in the later stages. All three species reproduced.

(*b*) Under the conditions of these experiments, *Hoploderma magnum* showed a marked preference for ash litter. Attempts to obtain a quantitative estimate of the litter consumed were somewhat inconclusive, for a variety of reasons. However, a consumption of 0.35 milligrams per mite per hundred days, when cultured on ash litter at 4°-5°C. (approx. 40°F.) was obtained. Of this total about fifty per cent. was excreted.

(*c*) Examination of the excrement of *Hoploderma magnum* indicated that, apart from any chemical transformations, the role played by these creatures in the comminution of decaying leaf tissue was of a high order. The average size of the majority of the particles in the excrement was approximately .003 by .005 of a millimetre.

Further culture experiments by the writer with *Hoploderma magnum*, confirmed a very definite preference for broadleaf as opposed to conifer, and of ash to birch. The mites showed no clear cut preference for either conifer litter. An interesting feature was the presence of circular incisions in the conifer needles which appear to have been prepared for oviposition. Small piles of leaf debris beside each one indicated that some of the material removed was not consumed. This tends to confirm Jacot's (1939) observation that immature mites of the family *Phthiracaridae* spend a considerable portion of their early life within conifer needles. This aspect requires further investigation. Field observations made by Spencer in conjunction with his laboratory experiments, revealed very few *Hoploderma* mites under ash and birch stands, which suggests the interesting hypothesis that some of these organisms may play a part in the more rapid litter decomposition which frequently occurs in mixed broadleaf and conifer stands. The accumulation of conifer needles provides suitable environmental conditions, whilst the present of broadleaf litter provides palatable food material for the maintenance of litter-feeding populations of soil *Acari* at a high level.

Studies of the life histories of soil *Acari* have been continued, but progress has been rather slow. This is partly due to the limitations of present culture methods, as many of the mites, especially in the larval stages, are extremely sensitive to adverse conditions.

Miscellaneous Activities

An investigation of the funnel method of extraction of soil organisms has continued. It has not been possible to devote as much time to this work as the writer would wish, owing to the demands of the soil faunal survey already referred to. The writer carried out some experiments with phase contrast microscopy for the examination of *Acari*, and found this a valuable tool for the examination of certain species. The writer is much indebted for the advice and assistance he has received from Dr. Robert Barer of the Department of Human Anatomy, University of Oxford.

A paper, with photomicrographs, illustrating the possibilities of phase contrast microscopy in this sphere will be published shortly, under the joint authorship of Dr. Barer and the writer. In addition two exhibits were prepared for the exhibition organised by the Department of Forestry on the occasion of the opening of the new building by H.R.H. Princess Margaret last October. One of these was a pictorial tableau illustrating some of the organisms occurring in a Yorkshire moorland soil, and factors influencing their distribution in the profile. The writer was invited to read a paper to the Seventh Congress of British Entomologists, held in London in 1951.

Lastly the writer would like to acknowledge the encouragement and assistance he has received from many people during the course of the year. In addition to those already mentioned, he would especially like to record his thanks to Dr. B. M. Hobby of the Hope Department of Entomology, Drs. R. N. Chrystal and M. L. Anderson of the Department of Forestry, Oxford University, and Dr. F. A. Turk. Dr. G. O. Evans, now Acarologist at the British Museum (Natural History) has continued to offer valuable assistance in the identification of material. Indeed the re-establishment of this post has filled a gap in the ranks of systematy and provided a service, the absence of which has been sorely felt by those working in this branch of soil biology.

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Note by Chief Research Officer

Dr. G. O. Evans of Rothamsted Experimental Station was doing parallel work on the mesofauna of forest soils in conifer forests at Ampthill (Bedfordshire) and in broadleaved woodland near Rothamsted. He has since left to take up the post of Acarologist at the British Museum and has been succeeded at Rothamsted by Mr. P. W. Murphy from the Imperial Forestry Institute.

Dr. Evans writes to say that he has completed a programme of sampling and extraction in Sitka spruce plantations. The identification of the fauna is still in progress, and it is hoped to complete the work before the end of the year and to publish the results. The investigations include a study of the seasonal fluctuations in the fauna, and the life cycles and feeding habits of the dominant Orobatid mites.

The investigation of Orobatid mites occurring in the humus layers under coniferous and deciduous stands at Woburn and Ampthill, mentioned in last year's report, has been completed and the results are almost ready for publication.

BOTANICAL STUDIES OF THE VARIATION IN CERTAIN CONIFER SPECIES

By Dr. E. V. LAING
Department of Forestry, University of Aberdeen

The investigation into the variability of different species of conifers has been continued, with a view to establishing race or strain. Most emphasis has again been placed on the larches. Besides continuing to identify strains of European larch by cone, seed and wing, renewed attention has been paid to variations in Japanese larch and hybrid larch. The hybrid cones sometimes take after the Japanese parent, but more often the European parent. It is now possible to tell in many cases what strain has been the European parent of the hybrid larch.

The data is now getting complete enough to enable the identification of several strains of European larch, as for example from the parent larch of Dunkeld, Silesia, Austrian Tyrol, Carpathian and Swiss. The work has been much more complicated than had first been estimated, by the fact that few, if any, of the so-called race plots are pure. They each contain a number of strains. This is particularly true of the Silesian plots, in which there is often an admixture of Tyrolese larch.

It looks as if there will be more strains of Japanese larch than had been expected. Pronounced differences often exist in one and the same plantation, and sometimes what are taken to be Japanese larch trees are proving to be something else altogether, such as possibly *Larix gmelini.*.

Some fundamental work has been done on the differences in European, Japanese and hybrid larch seed, and on the determination of hybridity in the embryo and the newly germinated seedling. Differences exist in the internal structure of the cotyledons of the larches, and intermediate characters have been noted in the hybrid. Tests are being continued, and it is hoped to have a means available to tell whether a sample of seed from European or Japanese trees contains hybrids.

Further data has been collected on such species as *Pinus contorta, Picea sitchensis* and *Pseudotsuga douglasii.*

INVESTIGATIONS ON FOMES ANNOSUS IN EAST ANGLIAN PINE PLANTATIONS

By Dr. S. D. GARRETT
School of Botany, University of Cambridge

Sampling and recording of the experiments set up by Dr. J. Rishbeth in 1949, on methods of protecting the cut surface of freshly felled pine stumps against basidiospore infection by *Fomes annosus* (see *Report on Forest Research* for 1950), have been completed. The results of these and earlier experiments on the efficiency of three different types of stump protectant are given below, in Table 38:—

Table 38

EFFECT OF DIFFERENT PROTECTANTS IN CONTROLLING STUMP INFECTION BY FOMES ANNOSUS

Stump treatment	No. of sites	No. of plots	Mean % stumps with Fomes annosus	
			Untreated plots	Treated plots
Creosote mixture	1	4	38	6
2 Tar: 1 creosote	2	5	18	2
Paint	3	9	27	2

Treatment either with the tar-and-creosote mixture, or with a suitable quality paint has therefore given a high degree of protection against infection by *Fomes annosus* basidiospores, but it must be emphasized that the efficiency of these treatments depends upon *application immediately after felling.* Two types of paint were tested in these trials, an ordinary quality oil gloss paint, and a high quality titanium paint, and it is interesting to note that, so far as these experiments went, the poorer quality paint gave equally good protection. The superiority of the tar-and-creosote mixture over creosote alone is presumably due to the more plastic and durable covering afforded by it, with respect to development of cracks as the stumps dry out; the same consideration should apply to the relative performance of different types of paint.

In contrast with "passive" protection of stump surfaces against *Fomes annosus* basidiospore infection by one of the above protectants, experiments were also set up to test the possibility of "active" protection by inoculation of the stump surface immediately after felling with the fungus *Peniophora gigantea*, a natural competitor of *Fomes annosus* in pine stumps. Two methods of inoculation with *Peniophora gigantea* were employed: (1) the insertion of wedges taken from naturally infected stumps, (2) application of a spore suspension. Of these two methods of inoculation with *Peniophora gigantea*, the spore suspension method was much the more effective, and would probably prove as efficient as painting with a protectant. Nevertheless, in spite of its great scientific interest, this method of biological control cannot compete with the painting method as a practical control measure, with respect either to convenience or to cheapness.

The major part of Dr. J. Rishbeth's work on *Fomes annosus* in East Anglia has now been published in the form of three papers in the *Annals of Botany* (Vols. 14 and 15, 1950-51); the remainder will be published in *Forestry.*

EFFECT OF PARTIAL STERILIZATION ON THE FUNGAL FLORA OF AN OLD FOREST NURSERY SOIL

By Dr. J. H. WARCUP
School of Botany, University of Cambridge

Treatment with steam or formalin markedly affected the fungal flora of an old forest nursery soil. The untreated nursery soil contained two soil layers, the lower of which was characterised by a very poor fungal flora. Some fifty-five species were of frequent occurrence in untreated soil, and common genera in the upper layer were *Pythium*, *Absidia*, *Mortierella*, *Mucor*, *Aspergillus*, *Fusarium*, *Gliocladium*, *Penicillium*, *Phoma*, and *Trichoderma*. Both with steam and with formalin treatment, fungi were initially destroyed or reduced to very low numbers. The penetration of soil by different treatments was sixteen inches for Hoddesdon steaming, eight inches for Canopy steaming, and five inches for formalin treatment.

Fungal recolonization of treated soil was slow, and even eighteen months after treatment numbers of species and colonies were much lower than in untreated soil. Steam-treated soil was recolonized chiefly by species of *Mortierella*, *Phoma eupyrena*, and *Coniothyrium* species in the first year. These species, with *Penicillium* species and sterile fungi, were present in the second year after treatment. Recolonizing fungi were usually most abundant near the soil surface. In formalin-treated soil, *Trichoderma viride* was the dominant recolonizer. *Phoma eupyrena*, *Coniothyrium* species and *Fusarium* species were also present, particularly in the second year.

Mean height and total number of Sitka spruce seedlings grown on the experimental plots were appreciably increased by soil sterilization with steam or formalin.

MEGASTIGMUS INSECTS ATTACKING CONIFER SEED

By N. W. HUSSEY

Department of Forest Zoology, University of Edinburgh

During the year, 260 samples of coniferous seed were examined for evidence of *Megastigmus* attack, and 95 were found to be affected, 26 being in imported seed lots. These samples were provided by the Seed Testing Stations at Cambridge and East Craigs, Edinburgh, and by a number of Forestry Commission Seed Extraction Plants including those at Tulliallan, (Fife), Santon Downham (Suffolk), Durris (Kincardine), and Newton (Morayshire). The tree species principally affected were Douglas fir and silver fir, the former by *Megastigmus spermotrophus*, Wachtl., and the latter by *Megastigmus pinus* Parfitt. Characteristic exit holes were also observed in a number of samples of Norway and Sitka spruce, and European, hybrid and Japanese larches, but no insects were obtained. A considerable quantity of Corsican pine seed from the Thetford Forest, Norfolk, was found to be affected similarly, but no insects remained in the seed, and as the presence of *Megastigmus* has not previously been shown in any member of the genus *Pinus* in Europe, the damage cannot yet be said to be attributable to this genus.

The common *Megastigmus spermotrophus* was found to be widespread in its occurrence in England and Scotland, and was bred out from seed of Norway Spruce and *Abies grandis* in addition to its normal host the Douglas fir.

Megastigmus pinus adults were bred from *Abies nobilis*, whilst from *Abies grandis* seed from Novar Estate (Ross) a similar but smaller and more yellow form has been identified as *Megastigmus milleri* Milliron.

Although the percentage of total seed infected by *Megastigmus* was found to be generally small, the fact that the insect oviposits only in sound, potentially fertile, seed, together with the high proportion of naturally "shrunken" seed on home-grown exotics, makes the economic loss considerable. Several centres as far apart as Kent and Ross-shire showed an infestation of one hundred per cent. of the potentially fertile seed.

In January, 1951, a Chalcid ectoparasite—at present awaiting identification—was found affecting about thirty-five per cent. of *Megastigmus* larvae on the Rosehaugh Estate, Avoch, Ross-shire. The biology of this insect is to be investigated.

Current work is designed to study the bionomics of two outbreaks of *Megastigmus spermotrophus*, one at the Bedgebury National Pinetum in Kent and the other in Avoch, Ross-shire, in order to ascertain details of the biology of the species, particularly fecundity, together with experiments to determine the extent of the biological control secured by mice, squirrels and parasites. Humidity and temperature requirements are under investigation in the laboratory.

THE NESTING OF TITMICE IN BOXES, 1950

By Dr. D. LACK
Edward Grey Institute for Field Ornithology, Oxford

The enquiry, organised through the Edward Grey Institute of Field Ornithology, Oxford, on the nesting of titmice in boxes, was continued very satisfactorily in 1950. The Forester Training School at Lynford Hall (G. Flint, F. Pridham) completed record cards for 201 nests in Thetford Chase, Norfolk. Charterhouse School Natural History Society (T. R. Garnett) completed 126 cards for Alice Holt Forest, Hants., J. M. D. Mackenzie completed 117 cards for Perthshire and Tentsmuir Forest, Fife, the Forester Training School in the Dean Forest, Glos., (Dr. B. Campbell, W. P. Lewis) completed 83 cards, Glentress Forest, Peebles-shire (W. Straughan) completed 40 cards, E. Cohen in Hampshire 30 cards, Merrist Wood Farm Institute, Surrey (R. N. Edmondson) 14 cards, and Gwydyr Forest, Caernarvonshire (R. J. Pearce) 11 cards. In addition, records of 108 nests were obtained by the Edward Grey Institute (J. A. Gibb, P. H. T. Hartley) in Wytham Wood, Oxford. In all, records were kept for the nests of 337 Great Tits, 264 Blue Tits, 132 Coal Tits, and 3 Willow Tits.

This large body of data enables accurate quantitative assessments to be made of the breeding season, average clutch-size and nesting success of the three common species of tits in different places and in different years. As compared with 1949, the spring of 1950 was warmer in late March and early April, but then there was a cold spell. As a result, the tits started to breed earlier in 1950 than in 1949, but then there was a hold up. Most of the Coal Tits started to lay before the cold spell, so that the breeding season was a little earlier in 1950 than in 1949. But the Blue Tits, which start shortly after the Coal Tits, were about two days later in 1950 than in 1949, and the Great Tits, the last of the tits to breed, were badly caught by the cold spell and bred about a week later in 1950 than 1949. As in 1949, the breeding season of all three species of tits was decidedly later (8 to 10 days) in the Corsican than in the Scots pine plantations a few miles apart at Thetford Chase. It is hoped to investigate this remarkable difference further. The breeding season was about a fortnight later in Scotland than in Southern England.

The average clutch-size of the Great Tit was rather lower in 1950 than in 1949, that of the Blue and Coal Tits was about the same (with local variations).

The seasonal decline in average clutch-size between late April and May was demonstrated for both Great and Blue Tits, as in former years. Nesting success was very similar to that in former years, the tits in most regions doing extremely well, but with a heavy mortality in the Corsican pine plantations at Thetford; the cause of this mortality is not certainly known.

In the areas where the nest boxes have been up only one to three years, the tit populations are still increasing, but in the Forest of Dean, where saturation has been reached, the Blue Tit showed a marked, and the Great Tit a small, decrease in 1950.

The investigation has now been continued for three years, and it is proposed to publish a comprehensive account after the completion of the fourth year in 1951. The results represent by far the most extensive survey of the nesting of any British species that has ever been attempted. The organizer would like to express his appreciation of the extremely hard work put in by the various helpers at the Forester Training Schools and elsewhere, without whose assistance these investigations could not have been undertaken.

FORESTRY COMMISSION PUBLICATIONS

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