FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1950

LONDON: HIS MAJESTY'S STATIONERY OFFICE
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General View of an Experimental Planting Area on difficult Peat. Lon Mor, Inchnacardoch Forest, near Fort Augustus, Inverness-shire

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PART II: RESEARCH UNDERTAKEN FOR THE FORESTRY COMMISSION BY WORKERS ATTACHED TO UNIVERSITIES AND OTHER INSTITUTIONS

INTRODUCTION

By JAMES MACDONALD
Director of Research and Education

This report, which is the second to be published, gives an account of the work in Forest Research which has been carried out during the year ended 31st March, 1950. It is divided into two sections, the first dealing with work carried out by members of the staff of the Forestry Commission, and the second with work on special problems undertaken for the Commissioners by Universities and other Institutions. The various sections have been written by officers and scientific workers who have been engaged on the subjects during the year, and a general summary has been contributed by the Chief Research Officer, Mr. M. V. Laurie.

The work carried out by the research staff of the Forestry Commission has been expanded by the inclusion of a section dealing with the problems arising out of increasing mechanisation in forestry. The Machinery Research Officer who has been appointed for this work has undertaken a large programme of investigation designed to cover the mechanisation of some of the more important operations in the forest, amongst which are ploughing, extraction and preparation of produce, and transport.

In silviculture, it has been possible to pay much more attention to the important problem of the rehabilitation of the large areas of derelict broadleaved woodland, and it is expected that this project will be extended considerably in the next few years.

The work on soils and on mycorrhiza financed by the Commissioners has continued at the Imperial Forestry Institute, Oxford, at Rothamsted Experimental Station, at the Macaulay Institute for Soil Research, Aberdeen, and at Bedford College, London, while the work on the morphology of forest trees has gone on under Dr. E. V. Laing at the University of Aberdeen. An increase, during the year, of the grant paid to this University has made possible the appointment of a Research Student who is studying the morphological and silvicultural variations of the Scots pine, and who will pay particular attention to the remnants of the old native pine forest of Scotland.

During the year, the Advisory Committee on Forest Research met on two occasions. The first meeting was held at Strathpeffer, Ross-shire, from 30th September to 2nd October, 1949, and the second, on the 15th December, in London. At those meetings, the report on Forest Research for last year and the programme of work for the current year, were discussed, while the opportunity was taken at Strathpeffer of inspecting some of the experimental work in the Black Isle, and of visiting other forest areas in the neighbourhood.

The Sub-Committee on Nutrition in Forest Nurseries has met on two occasions, at Northerwood in June, 1949, and at Oxford in October of the same year. At both meetings Professor F. T. Brooks presided.

Numerous visits have been paid to various scientific Institutions in this country by members of the Research staff. These visits have been valuable, particularly to the younger research officers, and thanks are due to the Directors of these Institutions, some of which are mentioned in this report, for the help which they and their staffs have so kindly given.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE
Chief Research Officer

Staff

The major change in the staff of the Research Branch was caused by the completion of the Census of Woodlands. Most of the field staff had been dispensed with by the end of the year under review, and Mr. J. S. R. Chard, Chief Census Officer, was the only officer remaining, while he finished writing up the results. Mr. G. M. Locke was put in charge of the Census records, working under the Mensuration Officer.

Mr. J. L. F. Fergusson of the Census was transferred to the East Scotland Conservancy, and Mr. P. C. Gough, Assistant Silviculturist, to the Education Branch. Mr. A. M. Mackenzie of the Census became Assistant Mensuration Officer.

Other new appointments were Mr. D. Bevan (District Officer II) as Assistant Entomologist, Mr. J. S. Murray (District Officer II) as Assistant Pathologist, and Mr. A. D. S. Miller (District Officer II) as Assistant Silviculturist working on problems connected with the rehabilitation of Derelict Woodlands. Mr. I. A. Anderson was appointed as Senior Photographer.

The Forest Research Station, Alice Holt

The installation of mains electricity was satisfactorily completed. Work on the construction of a constant low temperature room is well advanced. It will be used not only for seed storage but also for storage of living material for the Geneticist, Pathologist, and Entomologist. Two huts were erected to accommodate the overflow from the main building.

Over fifty official visitors came to see the Research Station during the year. They included representatives from the following countries: Australia, Brazil, British Guiana, Canada, Ceylon, China, Denmark, France, Germany, Holland, Kenya, Norway and the United States of America.

The Year's Work

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

1. FOREST TREE SEED INVESTIGATIONS

Work has continued on chemical staining methods for testing tree seed using tetrazolium bromide, and indications are that the results of these tests give a close correlation with the germinative capacity as determined by the standard Copenhagen Tank Method, and with actual germination results in the nursery. Systematic work on the storage of seeds for different species has been commenced. Lime and beech seed were found to store best at low temperatures (5°C.) in moist sand or peat.

2. EXPERIMENTAL WORK IN THE NURSERY

Work was continued on the effects of partial soil sterilisation in established nurseries. Residual effects of sterilisation in the previous year, both by steam and formalin, were found to be marked. Studies in the technique of steaming were continued in an endeavour to find more efficient and cheaper ways of carrying out the operation. With regard to formalin, studies of different methods of application, to increase the effectiveness of the chemical, gave

promising results. An experiment in placing phosphatic fertilisers beneath seed drills, which in the previous year gave negligible results, was very successful in increasing the growth of Sitka spruce seedlings this year. It will be repeated next year for confirmation. In heathland nurseries, work was concentrated on determining how to maintain an optimum level of fertility with minimum cost in fertilisers and composts. With regard to forms of nitrogen for application in nurseries, it was again confirmed that "flash" (a waste product of plastic button manufacture) was the best form of nitrogen and at the same time cheap.

Trials with numerous composts, including a long-term composting and fertility maintenance demonstration at Wareham, were continued.

The series of experiments on watering seedbeds was concluded, the main result being that under most soil conditions considerable increases in the number of usable seedlings are obtained by watering in dry periods, provided that adequate nutrients are available in the soil. The best results were obtained from watering in soils which had had liberal applications of compost. Work has been extended on the use of selective weed killers in seedbeds, and preliminary indications are that some of the aromatic oils are relatively poisonous to weeds, while not so damaging to coniferous seedlings. More work is required before satisfactory chemical weed control methods can be prescribed.

3. NURSERY EXTENSION EXPERIMENTS AT RADNOR FOREST

Some early nursery extension experiments in Radnor Forest, dating back to the period 1921 to 1927, have been finally summarised, and have given mainly negative results. Such nursery treatments as different densities of sowing, different spacings of transplants in the nursery, and grading of transplants, had little effect on the survival and subsequent growth in the forest in most species.

4. EXPERIMENTS IN PLANTING ON UPLAND HEATHS

Only a limited amount of new work is being done in this field for the moment, but the results of a very large number of old experiments are being summarised for publication. A brief review of some of these is given in this report. Ground preparation for planting is mentioned, describing the stages of development up to the current procedure of deep single-furrow ploughing, the beneficial effects of which are largely attributable to the suppression of heather by the spoil. The position of planting on these furrows has been tested, and in a number of instances it has been found that the best initial results are obtained from planting in the furrow bottom, a fact that leads to speculation on the factors at work and the future root development of such crops. Nurse crops and mixtures are mentioned. Frequently, the more difficult species on heathland types such as Douglas fir, Sitka spruce, and *Tsuga* can be successfully established, using either broom or a pine as a nurse crop from the start. Much more work on mixtures intended to last the whole or the major part of the rotation is required, and in this it is important to define clearly the objects we have in view in growing such mixtures. Manuring at the time of planting on heathlands has clearly indicated the advantage of using both phosphates and nitrogen on the poorest heather types, even for pines. Recent work on planting one-year seedlings has, as expected, given rather variable results. In favourable seasons, outstandingly successful establishment of plantations has been achieved very cheaply, and even in bad seasons the total cost of planting with seedlings, followed by replacement of up to thirty per cent. casualties, may be cheaper than complete initial planting with transplants.

Historical reports on heathland experiments at Hamsterley Forest (Durham) and Allerston Forest (Yorkshire, North Riding) are briefly reviewed, and a note on an investigation into the causes of failure of Sitka spruce to grow

properly on certain sites at Clashindarroch Forest (West Aberdeenshire) is given, together with recommendations for treating the various ground types where initial planting had failed to give a crop.

5. PLANTATIONS ON PEATLANDS

On peatlands some preliminary draining experiments demonstrated that, in dry periods, a drop of up to fifty per cent. in the depth of the water table can be achieved in one season by deepening nine to ten inch drains to thirty inches, thereby greatly increasing available rooting volume in the soil. New work is aiming at determining the long-term effects of increased drainage, including its effect on the stability of the crop.

A start has been made with trial plantations of various species, pure and in mixture, to ascertain whether economic crops can be grown on high level heather areas in the Border forests, and on the difficult peatlands in Caithness and Sutherland, both types hitherto considered unplantable.

6. DERELICT WOODLAND INVESTIGATIONS

The rehabilitation of derelict broadleaved woodlands is now the most important project on the programme of the Silviculturist South, and a specialist officer is giving it the whole of his attention.

At Alton Forest, Hampshire, a fairly typical derelict woodland on the chalk, a demonstration area has been taken over, stock-mapped in detail, the types of growth and condition of the crop classified, and a detailed plan of treatment drawn up. Two of the main features of derelict woodland work are the high cost of clearing of coppice and other regrowth for planting, and the high cost of keeping this regrowth in check while the planted crop becomes established. Experiments are concentrated on these two main aspects, and in addition to partial methods of clearing in strips and groups, control of regrowth by the use of chemical arboricides is being attempted. So far hazel coppice, blackthorn, rhododendron and ash coppice have been treated with a large number of chemicals, the most promising of which are ammonium sulphamate and sodium arsenite. Growth substances such as "M.C.P.A." and "T.C.P.A." give good kills of shoots, but do not kill the stumps so well as the sulphamate and arsenite.

7. FOREST GENETICS

Possible methods of improving the inherent quality of the trees in this country are described more fully in a subsequent section. They include the selection of seed stands in the best of our older woodlands and treating them to eliminate inferior trees, individual selection of elite mother trees, and finally the selection and propagation of both parents, testing them, and ultimately planting them in special seed plantations.

In Corsican pine a number of seed stands have been selected, and, in addition, twenty-one single trees have been marked down for propagation and comparative testing. Means of improving the seeding of Corsican pine are being investigated. For propagating elite material, grafting was fairly successful, provided the root-stocks had been in the ground for a full year before use.

Sowings of beech seed of different provenances collected in the 1948 seed year indicated that vigorous lots could be differentiated in the nursery bed. Differences in branching types and degree of forking were apparent, but these need to be observed for some years before it can be certain to what extent they are characteristic.

Material from twenty fine elite trees of European larch from old Scottish plantations has been propagated, and the formation of an experimental "seed orchard" of this species is now a practical proposition.

In Scots pine, mother trees have been selected, propagation started, and experiments on suitable "dwarfing" root-stocks for pines in general have been initiated.

With Sitka spruce, attention has been paid to the location and propagation of late flushing individuals, and of trees that exhibit relative immunity to the Green Spruce Aphis (*Neomyzaphis*).

Thuya has been used as experimental material in studying the best conditions for vegetative propagation, i.e., best type of cutting, best part of tree, best time of year, best medium to use, best hormone treatment, and best temperature and humidity. These experiments have also been repeated with × *Cupressocyparis leylandi* and *Metasequoia glyptostroboides*, both of which are particularly easy to raise vegetatively.

The geneticist made a short tour of continental tree breeding stations in Holland, Belgium, Denmark and Sweden, to study their methods of working.

8. PROVENANCE STUDIES

In beech provenance studies, planted in 1942 at Savernake Forest and in Abbotswood (Forest of Dean), a Dutch origin and a lot from West Dean (Sussex) both lead in vigour, and both show, so far, a low percentage of forking. As usual the Nagshead (Forest of Dean) plants are worst both as regards growth, and form.

Scots pine provenance experiments seventeen to eighteen years old have had their first thinnings, and an estimate of crop volume and increment has been possible. The Finnish and Norwegian lots and one Scottish race (Glenmoriston) come out lowest, followed by Riga (Latvia) and Trentino (Italy). The best races for vigour were from Sopron (Hungary) and Kassel (Germany), closely followed by East Anglia, and Wangenbourg (France). The best Scottish origin was considerably lower. In height growth, the East Anglian race came out ahead. The best Scots pine origin (Sopron, Hungary) had, at this stage, only about two-thirds of the volume production of Corsican pine on similar sites.

Reports on the provenance experiments with Corsican pine, maritime pine and on the 1946 International Larch Provenance Experiments (thirty nine different origins) are included.

9. SPACING OF OAK IN PLANTATIONS

The results of these early trials are finally summarised and indicate that close spacings of 4 feet × 2 feet are definitely wasteful. A spacing of 4 feet × 4 feet results in satisfactory stocking, given seed of a good source, a reasonably suitable site and proper weeding. Bunch plantings at wide centres (5 feet × 4 feet) gave the best stocking and distribution of desirable stems, but there was no advantage in increasing the number of plants per bunch from three to six.

10. SPACING EXPERIMENTS IN CONIFERS

Early spacing trials—namely 1935-36—were assessed, and future treatment determined. Of 145 original experiments, only 86 survived in a state suitable for complete assessment. Spacings were 3 feet, 4½ feet, 6 feet and 8 feet, in most experiments, and covered all our commoner species. Results showed that, in this country, variation in spacing had no significant effect on height growth, which is surprising in view of the different dates on which the different spacings closed canopy. Percentage survivals were similar in all spacings for any given site, but denser plantings of European larch suffered the worst from die-back. Studies were made of crown spread, branch thickness and individual stem diameters, all of which increased with wider spacing, while stem form, length of bole and taper were better in the closer spacings, as would be expected. The indications are that spacing should be varied according to site conditions,

and that on good sites wider planting distances than those current at present could be adopted.

11. STUDIES OF GROWTH AND YIELD

Forty-five new sample plots for yield table purposes were established, bringing the total to 427. Compilation of volume tables for all our more important species proceeded, and those for oak, beech, birch and Scots pine were ready for publication by March, 1950. In connection with the Census of Woodlands, the field and computation work for estimating standing volume and increment was completed. A study was made of the increment of "free-grown" oak, from which a simple relationship between crown diameter and breast-height stem diameter was established, and a rough yield table for "free-grown" oak was constructed. Methods of sampling thinnings were investigated, and recommendations issued; and a study of the apparent losses in small thinnings due to different methods of measurement at different stages was also made. Correlations between current height growth and volume production in conifers were worked out for different height classes, to provide an easy method of making rough estimates of production per acre.

12. FOREST ECOLOGY

The Ecologist's work has mainly been concentrated on a study of the ecology of beech, and in his report he mentions four of the finest beechwoods in the country, and discusses the conditions under which they were grown. Soil acidity, it is clear, is not of itself a limiting factor, as good beech can be grown on soils ranging in pH from 3.5 to 7.0.

13. FOREST PATHOLOGY

Observations and investigations are continuing on some twenty diseases of forest trees in this country. The spread of *Fomes annosus* from the stumps of freshly felled trees can be largely controlled by coating the stumps with a mixture of tar and creosote. An interesting alternative possibility of infecting the stumps with a harmless fungus to the exclusion of *Fomes* is being tested. A serious outbreak of *Melampsora pinitorqua* on Scots pine has pointed to the inadvisability of growing this species anywhere where aspen, an alternative host to the fungus, is present. Work continues on the propagation of clones of *Pinus strobus* reported to be resistant to blister rust. Concern has arisen regarding the dying of groups of Sitka spruce in various parts of the country. No definite pathogens have so far been isolated, and present theories tend to physiological explanations. In view of the importance of this species, and the large scale on which it is being planted, intensive study of this type of dying has been initiated. First trials of *Thuja* sowings in isolated nurseries indicate that seedlings free from *Keithia* can be raised if so isolated, though how long such nurseries can be kept free from the disease remains to be seen. Poplar trials have been continued and extended. The number of clones now under observation is 216. The testing of varieties for canker resistance has continued, and is bringing to light some promising disease-resistant varieties. The Sycamore Disease, which suddenly appeared recently at Wanstead, Essex, has been the subject of intensive survey, and it is now found to extend to Plumstead, Kent, to Staines, Middlesex, and to a point near Guildford, Surrey. The causal fungus, which has not yet been identified, has also been found as a saprophyte on fence posts.

14. FOREST ENTOMOLOGY

Work has largely concentrated on a survey of sawfly pests, and in particular the Large Larch Sawfly, which has started to appear in a number of centres

similar to those in which the serious epidemic occurred in 1906-1910. A study of the parasites occurring in the present outbreaks is also being made concurrently. Notes on four other larch sawflies, and a number of spruce sawflies, are also given, as well as on the bark beetle *Polygraphus polygraphus*, which attacks spruce trees particularly when already attacked by the sawfly *Pristiphora subarctica*. Sawfly parasites have been imported from Canada, bred up at Alice Holt and released in the forest.

Aphid pests of spruce have also been studied, and it appears that where serious effects on spruce from aphis attacks are experienced, the Green Spruce Aphis (*Neomyzaphis abietina*) is accompanied by a number of other minor pests.

15. MACHINERY RESEARCH

A Headquarters Mechanical Development Committee was formed in September, 1949, and a programme of investigations into the use of mechanical methods in the forest was drawn up and agreed. The main lines of investigation have concerned tractors, cable ways, and chutes; work has also been done on peeling by machines, and on the use of power saws in the forest. Studies have also been made of each phase of transport from the stump to the depot.

Part I of the Report concludes with notes on the progress in documentation work in the library, and the development of the photographic section.

Part II of the Report deals with work carried out by members of universities and other institutions. These investigations are financed by grants from the Forestry Fund, and in a number of cases assistance is also given by the Forestry Commission Research staff in carrying out field work.

16. SUB-COMMITTEE ON NUTRITION PROBLEMS IN FOREST NURSERIES

Dr. E. M. Crowther of Rothamsted Experimental Station reports on work done in 1949, for the Sub-Committee on Nutrition Problems in Forest Nurseries. An extensive series of seedbed experiments was carried out in thirteen different nurseries. In seedbed experiments in which composts and bulky organic manures were compared with artificial fertilisers, markedly poorer stands of seedlings were obtained in the compost treated beds. This was a reflection of the drought effect, in a particularly dry season, in soils lightened in texture by bulky organic manures, and confirms experience in similar experiments done by the Research Branch. Soil acidification experiments have provided useful information on the degree of damage to be expected when sowing follows applications of acid by too short an interval. Where an adequate period elapsed between acidification and sowing, improved growth of seedlings was obtained in Kennington nursery (near Oxford) and at Ampthill (Bedfordshire).

Experiments in which soil pH was artificially varied gave interesting results regarding the tolerance of different species to different degrees of soil acidity, but results were less striking than in the previous year. Partial sterilisation with formalin again gave excellent results on neutral and moderately acid soils, and at Ampthill Nursery (Bedfordshire) the results of such sterilisation with formalin and also with steam were dramatic. The microbiological changes in partially sterilised soil are being studied by the Rothamsted microbiology department.

In transplanting experiments, as well as in forest planting experiments of seedlings and transplants, it was confirmed that there was no apparent advantage (in respect of growth and survival of the plants) in raising them in compost-treated seedbeds as compared with artificials; plants of equivalent size raised with artificial fertilisers in the nursery grew just as well as transplants or in the

forest. Nursery bed rotation experiments were continued, but it will be some years before these yield reliable conclusions. Responses to fertilisers applied at the time of planting in the forest were smaller in this dry season than in the previous year. A positive reponse of Sitka spruce to phosphate was consistent in all four forests where the experiments were done. Scots pine did not behave so regularly and was even reduced in growth by phosphate applications at King's Forest (East Anglia). Nitrogen, as might be expected in a drought year, depressed growth of both Sitka spruce and Scots pine in all forests except Broxa, Allerston Forest (Yorkshire, North Riding), where it had a slight beneficial effect. Trials of fertilisers in the form of pellets, with the object of reducing the speed of diffusion and prolonging the time of action, and also for reducing the risk of damaging roots during periods of unfavourable weather, did not achieve the first object, as the soluble nutrients dissolved out of the core of gypsum at a much faster rate than had been hoped.

17. MICROBIOLOGICAL EXPERIMENTS AND COMPOSTS

Experiments with composts and root inoculations were carried on by Dr. Ida Levisohn at Bedford College, London, mainly in pot experiments. The objects were not only to study mycorrhizal fungi but also to analyse the phenomenon of haustorial infection so frequently encountered in run-down nurseries. It was found that different organisms varied considerably in their virulence. The behaviour of various soil fungi in breaking down organic matter in composts was also investigated. Experiments have been started to determine the effect of non-infective filtrates from mycorrhizal pot cultures, on the growth of seedlings of the same species in sterile soil.

At Sugar Hill Nursery (Wareham Forest, Dorset), routine cultural procedures were continued. An account of the work started by Dr. Rayner in this nursery has been prepared for publication.

18. EFFECT OF PARTIAL STERILISATION ON THE OCCURRENCE OF FUNGI IN THE SOIL

Mr. J. H. Warcup of the Botany School, Cambridge, presents some interesting results of the effect of partial sterilisation, by steam and by formalin, of soil at Ampthill Nursery, Bedfordshire, where the response of Sitka spruce seedlings to sterilisation was very large. Before treatment the soils were found to contain over 100 species of fungi. In the steamed plots all fungi were killed down to a depth of about twelve inches, and in the formalin plots down to four to six inches. Re-infection started from the surface after about six weeks in the steamed plots, and nine weeks in the formalin plots. Re-infection was mainly by *Trichoderma viride* in the formalin plots. In the steamed plots *Trichoderma* was the commonest species to come in, with *Mortierella* and *Coniothyrium* as associates.

19. INVESTIGATIONS ON THE FAUNA OF FOREST HUMUS LAYERS

Dr. G. Owen Evans of Rothamsted Experimental Station has been working on this subject for the past eighteen months. Techniques for extracting mites and other mesofauna were investigated, and ecological studies were made on the occurrence of these creatures in six forest sites covering both broadleaved and coniferous types. The numbers in beech and oak forest were larger (300-400) per square yard, than in conifers on various soils (160-300). Oribatid mites were the dominant form on all six sites. Considerable progress has been made in the difficult task of identifying the different species. Vertical distribution in the soil has been examined, and studies on the feeding habits and life histories of the main species have been commenced.

20. SOIL FAUNAL INVESTIGATIONS

Mr. P. W. Murphy of the Imperial Forestry Institute, Oxford, has continued his work in the mesofauna of heathland soils with a thin peat layer at Allerston Forest, Yorkshire. This work is complementary to some extent to that of Dr. Evans, mentioned above, on non-peaty soils. Extraction methods have been improved for which special apparatus was designed and built. Quantitative assessments of the fauna of mites and other arthropods in the soil have been made. Absolute numbers were much lower on these peaty soils, and Trombidiforms were dominant on unafforested soils. Under forest growth, on similar soils, a richer fauna dominated by Oribatid mites was found. Investigations have commenced into the part played by the faunal population in the life of the soil and the breakdown of litter. Close co-operation was maintained with Dr. Evans at Rothamsted.

21. RESEARCH INTO THE PHYSICAL AND CHEMICAL PROPERTIES OF FOREST SOILS

Mr. P. J. Rennie, of the Imperial Forestry Institute, Oxford, continued his work on heathland soils in their natural condition, after ploughing, and after a forest crop had been established and had formed a closed canopy. The work included studies of moisture status, porosity, effect of pan depth, distribution of total and available nutrients, and ammonification in the litter horizon.

22. NUTRIENT UP-TAKE OF CONIFERS

Dr. L. Leyton, of the Imperial Forestry Institute, Oxford, has worked on the nutrient status of Sitka spruce and of Scots pine and Corsican pine growing on heathland sites in the presence of, and in the absence of, *Calluna* (heather). The greater severity of the check in spruce, as compared with pines, in ground dominated by *Calluna*, can be attributed to the different rooting habits of the tree species in relation to *Calluna*, and is reflected particularly in the relative up-take of nitrogen.

23. ECOLOGICAL STUDIES ON CALLUNA HEATHS

Mr. G. W. Dimbleby has been studying the ecology of the Broxa (Allerston Forest, Yorkshire) heathland soils from an historical point of view, and suggests that afforestation difficulties largely arise from the podsolisation that has followed clearance of the original hardwood vegetation and colonisation by *Calluna*. Field experiments have been started to prove his hypothesis that the best way of improving these soils is by establishing birch or other hardwoods. He does not consider that ploughing will effect any permanent improvement, as the podsolisation will continue under a conifer crop.

24. ECOLOGICAL STUDIES IN PINE PLANTATIONS

Dr. J. D. Ovington, working at the Macaulay Institute for Soil Research at Aberdeen, continued his studies of the ecological changes that take place on sandy soils as a crop of pines becomes established.

25. BOTANICAL STUDIES OF VARIATION IN CERTAIN CONIFER SPECIES

Work has been continued by Dr. E. V. Laing, of the Forestry Department, Aberdeen University, on variations in Scots pine, and attention is now being directed to Douglas fir and Sitka spruce.

26. FOMES ANNOSUS IN EAST ANGLIAN PINE PLANTATIONS

Mr. S. D. Garrett has continued the work started by Dr. J. Rishbeth, of the Cambridge Botany School, on *Fomes annosus*, a fungus causing heart-rot in

conifers. Tar-creosote treatment of freshly-cut stumps in thinning has reduced the incidence of *Fomes* attack to only 3 per cent. Experiments are progressing in inoculating stumps with *Peniophora gigantea*—a fungus that is antipathetic to *Fomes*, in the hope of securing biological control by this means.

27. ORNITHOLOGICAL INVESTIGATIONS IN FORESTS

Dr. D. Lack and Mr. Hartley, of the Edward Grey Institute for Field Ornithology at Oxford, continued the studies on the nesting of titmice. Marked increases were obtained in the second year (spring, 1949) in the occupation of bird boxes. The study of the feeding habits of tits continues. In two pine areas, where nesting rates were good, there was an abnormal fifty per cent. mortality among blue and great tits, due to starvation in the nest.

Part I. Work Carried out by Forestry Commission Staff

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES
Assistant Silviculturist

The organisation and equipping of the Seed Testing Laboratory at Alice Holt continued during 1949. Four new Copenhagen tank germinators were added to the equipment, which means that up to thirty seed samples can now be tested concurrently.

The function of the laboratory is primarily research on seed problems, but in addition, a considerable amount of routine germination testing is done on all lots of seed which are used by the Research Branch, and on a number of imported seed lots that arrived late in the season.

The work of the laboratory covers seed testing, pre-sowing treatment and storage, and it is intended to extend this to include collection and extraction problems. Careful records are kept of the quality and subsequent performance of all lots of seed passing through the laboratory, and these records are being used for investigation of such points as the variation in seed numbers per pound within a species, the principal causes of low viability in various species, the most satisfactory methods of sampling and testing, etc.

Seed Testing Methods

The work, commenced during 1948, on the development of chemical staining methods for testing tree seed, was continued. The staining agent used was 2, 3, 5—triphenyl-tetrazolium bromide, which is reduced by photo-chemical means to an insoluble red dye, when in contact with living tissue. The technique now used allows full examination of the embryo staining areas in the seed sample under test. A large experiment was undertaken in 1949 to test the significance of the various staining categories distinguishable in each sample. These investigations were carried out on three species; Corsican pine, European larch and Sitka spruce. In order to cover a range of seed quality, seed of five different origins was tested in each species.

Comparison was then made, of the "germination" values indicated by the chemical method, with the standard Copenhagen tank method and also with the actual germination in test field sowings in five different nurseries.

It is clear that the tetrazolium method gives an accurate estimate of field germination; in fact the indications are that it gives a more accurate estimate than the standard germinator methods. By examination of the intensity of staining, it has been possible to distinguish vigorous and weakly embryos within the live class, and from this make some estimate of the percentage of seed which is likely to germinate under good or adverse soil conditions.

A chemical test is now always applied to sound seed remaining un-germinated at the end of a germinator test, and the stained fractions added to the germination

figure, to calculate the germination percentage. Ungerminated and unstained embryos are not included. In the course of other experiments it has been found that this procedure gives a close estimate of true germination capacity.

The principal advantage of the chemical method is the fact that a test can be completed in twenty-four hours, compared with up to thirty or forty days for a standard test.

Experiments to accelerate the germination rate in standard germinators by light irradiation and other treatments are as yet inconclusive, but are being continued.

Seed Storage

Alternative methods of short-term storage of lime (*Tilia*) and beech seed were tested, and it was found that low temperature storage (5°C.) in moist peat gave better results than any of the other methods tested, which included dry cold storage (5°C.) in sealed containers, and storage at normal room temperatures, both dry and stratified in moist sand and peat. Even dry cold storage in a sealed container gave poor results with these species, though the germination of beech increased during the four months storage period. The chief danger with moist storage or stratification is pre-germination, which will proceed vigorously after three or four months storage if the moisture content of the stratifying medium is too high.

The following table is an extract from the sowing data for the stored seed. Note the effect of four months dry cold storage on beech seed.

GERMINATION PERCENTAGE OF BEECH AND LIME SEED AFTER COLD STORAGE

Table 1 — Sown in seed pans

	Months of moist cold (5°C.) storage				Months of dry cold (5°C.) storage				Dry storage at normal room temperature for 4 months
	1	2	3	4	1	2	3	4	
Beech	2	77	83	88	0	16	18	54	17
Lime	13	19	31	39	1	0	0	0	1

Similar tests on Japanese larch, Sitka spruce and Corsican pine, showed that storage at room temperature in sealed containers, was as good as any of the other methods tried for such short term storage.

The effect of cold dry storage of beech seed for longer periods up to three or four years (approximate mast year frequency) is to be tested as soon as seed production allows.

Seed Treatment Prior to Sowing

CHEMICAL TREATMENT

Thiourea and ethylene chlorhydrin were tried as agents to stimulate the germination process in seed, but they gave completely negative results.

SOAKING IN WATER

Experiments carried out over the past three seasons at Kennington nursery, Oxford, show little evidence to support the practice of seed soaking prior to sowing. The three years in which the experiments were carried out included two dry seasons, and one moist one. There is no indication that the low response to soaking is increased or altered in any way by seasonal differences.

Soaking periods varying from one to thirty days were investigated; Sitka spruce, Norway spruce, Scots pine and Japanese larch were used as test species. The small germination increase recorded in 1948 for Sitka spruce after six days soaking, was not repeated in 1949. No effect on germination was apparent, apart from a marked depression of germination due to thirty days soaking. Norway spruce, Scots pine and Japanese larch also show no benefits from soaking. In all the species tested, germination is slightly reduced by soaking for periods exceeding twenty-four days.

It is quite apparent from inspection of the results over three years, that apart from slight initial stimulation of the rate of germination by soaking, the practical benefits from the treatment are small.

The slight acceleration of germination rate due to soaking may prove of value in the case of late sowings, but there is no definite evidence to show this.

EXPERIMENTAL WORK IN THE NURSERY

By M. V. EDWARDS and G. D. HOLMES

Assistant Silviculturists

Partial Soil Sterilisation

Last year's work with steam and formalin was continued.

Residual Effects of Sterilisation in a second year's re-sowings

At four nurseries where sterilisation had been effective in 1948, the original plots were re-sown without further treatment other than the repetition of the summer nitrogen top-dressing in Scottish nurseries and the application of hopwaste compost at the rate of twenty tons per acre before sowing at Kennington nursery.

(*a*) STEAM. The residual effect on mean height was marked at Benmore, Argyll (an increase of 0.76 in. =49% increase) and at Kennington, Oxford, (0.34 in. =56%) but it was negligible at Newton, Morayshire; and Fleet, Kirkcudbrightshire. The increase in number of seedlings produced was marked at Kennington (35 per square foot—350%) and Newton (29 per square foot = 22%) but it was small at Fleet and Benmore Nurseries. The residual effect on weed growth was the largest effect of all in the Scottish nurseries, where reductions of 24% to 83% in the time taken to do the weedings were obtained, as against 39% to 98% in the first season; but at Kennington, in spite of the marked reduction in the first year, it was entirely absent in the second.

(*b*) FORMALIN. Definite residual effects were obtained in all nurseries on the mean heights of the seedlings. Increases varied from 0.36 in. (25%) at Newton down to .024 in. (14%) at Fleet. The number of seedlings was increased at Kennington and Newton, but not elsewhere. Reduction in weeding time varied between 24% at Benmore to nil at Kennington.

Control of Steaming

Till now the only test of the success of a sterilization treatment has been that of the growth of the seedlings at the end of the season. Failure to obtain good growth has then been attributed to various uncertain causes.

A common one is probably the variation in the amount of steam injected into the ground, as this varies with the type of boiler, the pressure during the period of steaming, the size of the underground pipe system, the length and size of the feed pipe, and the amount that the steam valve is opened. It has been found that with the standard 7 ft. 6 in. × 11 ft. Hoddesdon pipe steaming area, the pressure at the inlet manifold (1¼ in. pipe) can be maintained at only 25 lb. per square inch for the twenty minute steaming period, even with the best boilers starting off at 125 lb. per square inch in the boiler. The 25 lb. pressure at the inlet manifold has therefore been standardised in Scottish comparative trials, and the main steam valve is adjusted to maintain it evenly. This has eliminated a serious source of error in past comparisons of steaming treatments.

The usual mercury and small bimetallic dial types of thermometer cannot be read in the cloud of steam that arises from the plot of ground, so that a copper constantan thermocouple system has been devised, reading through a switchboard to a micro-ammeter. This gives quick readings of temperatures in turn all over the plot of ground under treatment, with sufficient accuracy over the large range of temperatures involved. It proved better than the more accurate but slow-reading potentiometer.

Experimental Results

An experiment with three different periods of steaming (controlled at 25 lb. at inlet manifold) with the soil artificially brought to three degrees of moisture content, was carried out at Tulliallan, Fife; Newton, Moray; and Fleet, Kirkcudbrightshire.

The effects of steaming closely followed the temperatures attained. Temperatures of 150°-165° gave increases in mean height of .012 to 0.19 in. only, but temperatures over 182° gave increases in height 0.60 to 0.65 in., averaged over all nurseries and treatments. In most cases twenty minutes steaming was necessary to reach the higher temperatures and best growth results. With the thermocouple apparatus, which is both simple and cheap, it is now possible to determine the efficiency of the steaming operation while it is in progress, thus avoiding wasted effort in steaming under unsuitable conditions.

The effects of steaming with varying soil moisture conditions were erratic and not significant except at Newton, where the clay content of the soil is relatively low. Here clear differences between the soil moisture treatments were obtained, the temperatures reached varied inversely with the moisture content, and the mean height of the seedlings followed suit. There was however an interaction on the number of seedlings, steaming in the dry soil reducing, and, in the wet soil, increasing the number. This is the first evidence with conifers of the "toxic effect" of steaming dry soil noticed in glasshouses and counteracted by flooding the soil with water.

A new series of experiments was laid down at Ampthill Nursery in Bedfordshire, which has been continuously cropped as a forest nursery for nearly twenty-five years. The soil, which overlies Lower Greensand, shows a low response to fertilizers and manures, and a very low level of production for conifer crops, and is typically "conifer sick". The response to sterilization treatments was very marked. Steaming proved highly effective in reducing subsequent weed growth, and both steam and formalin treatments greatly increased the height growth and total number of seedlings. Steam was superior to formalin in its effect on height growth and the yield of usable seedlings, but both gave results far superior to unsterilized control plots.

Seedlings from steam or formalin treated plots are sturdier and healthier in colour and have much larger root systems than plants from untreated plots.

Investigations were also made at Ampthill of the response to steam sterilization of Japanese larch, Douglas fir, Scots pine, Corsican pine and beech. The effect on seedling numbers was small, and only in Japanese larch was there an increased stock following treatment, but steam increased the mean height and outturn of usable seedlings of all species tested. Japanese larch showed a growth increase of nearly three inches, while Douglas fir and beech both had increases of over an inch. Scots and Corsican pines responded only very slightly.

A field trial comparing plants raised under the contrasting treatments has been laid down on poor *Calluna* ground to test residual growth differences.

Acidification

Plots in last year's experiments which gave positive results in favour of acidification were partly re-sown without further treatment, and partly placed under transplants.

The sulphuric acid had little residual effect, though in two of the three nurseries where it had been highly beneficial in the first season it was still significantly beneficial on transplants, but not on seedlings.

The effects of sulphur, as in the first year, were erratic, but on the whole beneficial. The markedly good effect of ammonium sulphate at Newton Nursery was repeated, but at the other nurseries results were as insignificant as in the first season.

Even on these sites, which were chosen because of their high soil pH, the residual effects of sterilisation were larger than those of the acidifiers; this repeats and confirms the first year results. The complete N.P.K. fertilisers were again highly beneficial, except at Tulliallan and the Royal Botanic Garden, Edinburgh.

It may be concluded that while acidification generally produces a clear beneficial effect on soils which are neutral or only slightly acid, these effects are usually small compared with those resulting from partial sterilisation. Occasionally, in some nurseries, results of either treatment are small or erratic, indicating that factors other than those affected by acidification or steaming are limiting the growth of the seedlings.

Manuring

Placement of Fertilisers

A simplified version of the experiment made in 1948 was carried out, omitting the second density of seed sowing and the lower level of application of fertiliser. This year it compared placement of phosphate by drilling, with broadcasting of phosphate, each combined with applications of potash and nitrogen, either drilled, or broadcast by the usual methods.

The effect of placement is necessarily complicated by the effects of drilling seed, since fertilisers cannot be placed under the normal broadcast-sown seedbed. But while drilling shows signs of being a less efficient method of sowing than broadcasting (see the following section on Method and Density of Sowing), drilling plus placement gave much better results in both the nurseries where the experiment was done. In fact at Fleet Nursery the advantage was very marked indeed, and the seedlings grown in this way were equal to the best heathland nursery seedlings. The experiment was carried out on ground sterilised with formalin, and the best treatments were those using flash (a waste product of button manufacture) as a source of nitrogen, either placed or broadcast, but the results with the standard nitrochalk also showed the advantage of drilling seed above placed fertilisers.

Phosphate was drilled in all placed treatments. There was little difference between drilling or broadcasting of potash or flash, but the drilling of all three together produced, on the whole, the best result.

As is usual in drills, the total number of seedlings was slightly reduced, but owing to the highly significant increase in height, the outturn of seedlings over one and a half inches in height was increased.

The experiment is being repeated to see if these results, which were not obtained in 1948, can be confirmed.

Organic and Inorganic Manuring in Heathland and Established Nurseries

In the heathland nurseries an established technique is in successful operation. The chief problem now is to maintain the manuring at the optimum level to produce the best plant at the lowest cost. An experiment to see, if, in case of a shortage of hopwaste, it could be replaced by a greencrop and inorganic fertilisers, was started during the year, following a successful indication at Achray Heathland Nursery (Loch Ard Forest, Perthshire) in 1947. Successful preliminary greencrops were grown at Littleburn Nursery, (Kilcoy Forest, Ross-shire), Roseisle (Morayshire) and Devilla (Fife) Nurseries.

The standard nitrogen/phosphate and potash dressing was maintained with success as in the previous year. This consists of superphosphate and sulphate of potash applied before sowing, and nitrochalk as top dressings during June and July.

An experiment to try various methods of application of nitrogen was carried out. The plastics, flash and formalised casein, repeated their successful results, and there is no doubt that these forms give both the best height growth and the greatest outturn of seedlings. No case of an inhibitory effect on germination, as frequently occurs with hoof-and-horn, has been noted. Fish guano and "vegetable organic meal" were used, but they reduced the outturn very seriously in some nurseries, and rarely increased the size of the seedlings greatly.

Composting and Trials of Compost

The long-term composting and fertility maintenance demonstration at Wareham Heathland Nursery was continued in 1949. The different sections of this nursery have now been managed under contrasting compost, green crop and mulch treatments since 1943.

The fertility in the composted sections remains high, but during 1949 the growth of all species as seedlings was much reduced owing to the exceptionally dry growing season. The deeper rooted transplants on composted sections withstood the drought well.

An important observation at Wareham in 1949 was the danger of extreme soil drying due to insufficient consolidation following compost application. This effect was not widespread, but where it did occur it caused serious loss of young seedlings.

There is good evidence from growth in 1949, that the increased organic matter content of the soil in regularly composted sections assists greatly in retaining moisture and reducing damage to seedlings during a dry year.

Compost Trials

Routine tests of experimental composts prepared during 1948 showed little difference in the resulting growth of seedlings for different kinds of materials composted, provided these had broken down well in the composting process. Bracken and hops still appear to make the best compost for most soils. Other materials such as shoddy (wool waste) produced a smaller response on woodland and arable soils. On a sandy heath soil, however, a shoddy compost gave better growth of seedlings and transplants than standard hopwaste. This effect was

almost certainly due to the better moisure retaining capacity of the wool waste in an exceptionally dry season, as compared with that of the other more bulky composts which tended to dry out more readily.

Composting Methods

During 1949, work was concentrated on methods of composting mixed conifer and hardwood sawdust. This material, which is such an abundant waste product, is one of the most difficult to break down. Several methods were tried, using a wide range of activators. Moderately good decomposition was obtained with hopwaste as an activator. A mixture of equal volumes of sawdust and hops seems to be the most satisfactory. Inorganic activators such as sulphate of ammonia produced no breakdown at all.

The most satisfactory sawdust composts were prepared with liquid blood or sewage sludge as activating agents. Owing to the offensive nature of the blood, a special technique was developed which reduced man-handling to a minimum. In this the sawdust was treated in bulk in bays constructed of straw bales. Blood was used at the rate of one gallon per cubic foot of sawdust. In four months the whole heap was a black friable mass with a heavy worm population. No water was applied throughout the composting process, and the heap was only turned once. Sewage sludge also gave an excellent breakdown of fresh sawdust. The high lignin content of sawdust appears to be the principal barrier to rapid decomposition, and this may require a new composting technique, possibly involving inoculation with specific lignin-decomposing fungi.

Grass Leys and Green Cropping

Experiments were commenced in 1947 at Kennington Nursery, Oxford, to test the value of a grass and clover ley crop in improving soil fertility. The land concerned had been cropped continuously prior to 1947, and showed some symptoms of conifer sickness, including low responsiveness to manurial treatment.

Plots were kept under a continuous two-year ley of perennial rye grass and white clover during 1947 and 1948. In 1949 the ley was dug in, and the ground lined-out with two-year seedlings of Sitka spruce.

At the end of 1949, there were no appreciable growth differences between plants lined-out on land which had been under continuous fallow, continuous transplants, or continuous greencrop since 1947. This conforms to previous observations that seedling or transplant crops show small response to green-crop residues during the first year after green-cropping. At Wareham Heathland Nursery during 1949, seedbeds on land green-cropped in 1948 showed much poorer growth than similar beds on land green-cropped in 1947 (vide Table 2). The green-crop used in this case was a mixture of Italian rye grass, oats and vetches.

MEAN HEIGHT OF ONE YEAR SEEDLINGS
RAISED ON LAND PREVIOUSLY GREEN-CROPPED

Table 2 — Seedlings raised in 1949

SPECIES	LAND GREEN CROPPED 1947	LAND GREEN CROPPED 1948
Japanese larch	8 inches	4 inches
Norway spruce	7½ ,,	2 ,,
Scots pine	3 ,,	2 ,,
Pinus contorta	3 ,,	2 ,,
Picea omorika	3 ,,	1½ ,,

This delay in green crop residual effects has been noted on a number of occasions at Wareham.

Method and Density of Sowing

The faster growth induced by the heathland nursery treatment, and by partial soil sterilisation, necessitates a re-determination of the optimum sowing density. At the same time more data on the relative merits of broadcasting or drilling seed are being collected.

In five nurseries where an experiment included both drilling and broadcasting of Sitka spruce seed at half-standard, standard, double and quadruple sowing densities, on both sterilised and unsterilised ground, the mean height of the seedlings tended to decrease slightly with increasing density, though there was little difference between the normal and half-normal densities of sowing.

The yield of seedlings per pound of seed was very significantly less with double the standard density, and still less with four times the standard density of sowing. Drilling reduced both the mean height and the yield of seedlings, especially at the higher densities.

There is also evidence that the ratio of the stem diameter of a seedling to its height, which is the simplest possible expression of its sturdiness, decreases with increasing density of the plants in the seedbed.

The preliminary conclusions to be drawn from this experiment, which is not complete, thus confirm that density above normal produces fewer, shorter and thinner plants per pound of seed; and they suggest that, at any rate in the first season, the effects of drilling are similar to those of the greatly increased density of the plants within the drill or band, in which the seedlings do not appear to be able to utilise fully the space between the drills.

The bad effects of abnormally high density have proved to be less on sterilised soil, which permits of an increase in density over normal without the corresponding seedling losses. Thus on the sterilised part of the experiment, even four times normal density gave nearly as good a percentage of usable seedlings, though this fell off very seriously on the unsterilised areas.

Drill sowings are reported to have an advantage over broadcast sowings on account of cheaper weeding in the former; but except in one experiment, this was not confirmed. On a big scale, however, the use of machines for weeding between the drills might prove advantageous.

Regarding the quality of plant produced by the two methods of sowing, not enough evidence has yet been collected to say whether there is any appreciable difference between plants produced from drill or from broadcast sowings.

Watering of Seedbeds

A series of experiments has been carried out over the past three seasons to test the effect of watering both composted and uncomposted seedbeds of Sitka spruce, during their first season. The amount and frequency of water application have varied according to the season and soil requirements; but in all cases two broad watering treatments have been distinguished. Light watering, where water was applied only when the soil became dry to a depth of half an inch, and heavy or frequent watering, in which the surface layer of the soil was maintained in a moist condition throughout the growing season. For instance, at Kennington, Oxford, during 1949, the light watering treatments received a total of 14 gallons of water (i.e., approximately 3.1 inches) per square yard over the whole season. The heavier treatment received 60 gallons (i.e. approximately 13 inches) per square yard.

The growth responses to watering have varied considerably from season to season. In a season such as 1948, with an evenly distributed rainfall, the increase of growth and production of seedlings due to compost application is

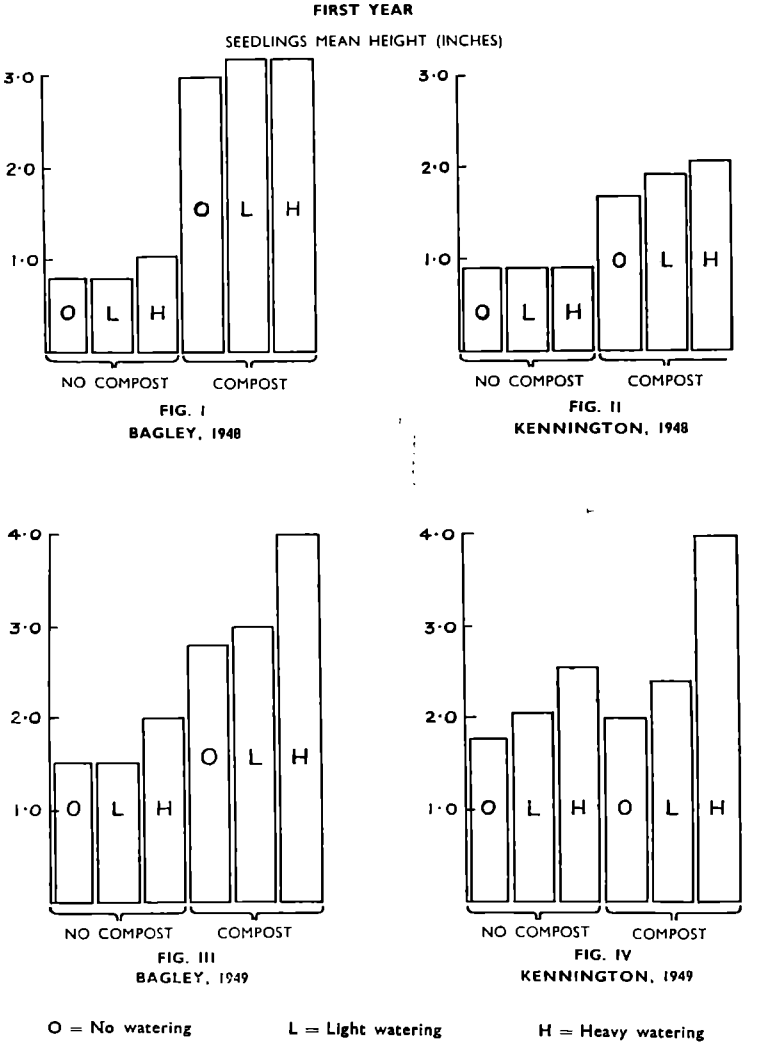
very much greater than any response due to watering treatment. This effect was obtained on three quite different soil conditions during 1948. (See Figures I and II).

The drier seasons of 1947 and 1949 resulted in a smaller response to compost, and a pronounced watering effect, especially on composted sections. One of the most striking features of the 1949 results was the very marked increase of growth due to watering in beds which had been treated with compost before sowing (see Figures III and IV). Conversely, adequate soil moisture is necessary for compost to have its full effect. At Wareham, in 1949, for instance, in compost treated beds, the outturn of usable seedlings was halved when watering

EXPERIMENTAL WORK IN THE NURSERY, BY M. V. EDWARDS AND G. D. HOLMES

SECTION HEADED: WATERING OF SEEDBEDS

FIGURES I—IV



was omitted. This is fairly definitely a drought effect due in part to insufficient consolidation of the beds following heavy application of compost—a condition which was remedied completely by watering.

Under most soil conditions, considerable increases in usable seedlings are obtained by watering. At Kennington and Bagley, during 1949, the production of usable seedlings was raised from 27,000 per lb. of seed to 54,000 per lb., as a direct result of watering. The hand watering methods used in the experiments are, however, impractical on a large scale, and preliminary trials are now being made with an overhead sprayline irrigation system.

Shading of Seedbeds

Experiments were continued during 1949 to determine the advantage of standard lath shelters for shading coniferous seedlings against excessive sun heat during the growing season.

Two sheltering treatments were tested, continuous lath cover over the beds from the date of sowing, and periodic lath cover when the shade temperature attained 70°F. for two consecutive days. During the hot, dry growing season of 1949, neither shading treatments showed any increase of seedling growth or production. Rising one-year seedlings of Sitka spruce and Japanese larch showed no response at all, while there was an appreciable depression of seedling production due to continuous shading in the case of Douglas fir.

The effects of shade have been tested on both early and late sown seedbeds of the above mentioned species. There is no change in the shade response between sowing dates, and it is clear that the increase in growth and production due to early sowing (early April) is of much greater importance than any shade effect. The results were very similar during the hot, dry season of 1947. In the moister season of 1948, the one beneficial response was an increase of 50 per cent. in the yield of usable seedlings of Sitka spruce with periodic shading.

It is important to note that these results were obtained in a nursery where it is regular practice to apply water to seedbeds in times of drought, and consequently any effects of shading on soil moisure would tend to be obscured. An attempt is being made in 1950 to distinguish between the shading and the moisture conservation effects of lath cover, by including watered and unwatered plots in the experiment.

Selective Weedkillers in Seedbeds

Experiments were continued during 1949 to test the possibility of selective control of annual weeds in conifer seedbeds by means of chemical sprays.

A range of compounds was tested during the course of the year, including Sodium methylchlorophenoxy-acetic acid (M.C.P.A.); di-nitro ortho cresol (D.N.O.C.); and Varsol (mineral white spirit, 16% aromatic oil). These compounds were applied to seedbeds as finely divided sprays, during June, 1949, when a heavy young weed population had appeared.

M.C.P.A. and D.N.O.C. showed very little selectivity in their toxic effects, between tree seedlings and weed seedlings. The sprays were tested at two stages of seedling growth; the first, shortly after germination, with tree seedlings in the cotyledon stage; and the second when the seedlings had developed their first primary needles. At both stages all application rates of M.C.P.A. and D.N.O.C. caused considerable damage to tree species and killed a number of seedlings. Varsol applied at volumes up to 100 millilitres per square yard, shows less toxicity to the tree species, producing no appreciable adverse effects on Scots pine and Corsican pine. Sitka spruce and Douglas fir are more sensitive, although the reduction in tree seedling numbers due to Varsol treatment is not as great as for the other compounds. Japanese larch was severely damaged by all treatments.

The weed crop consisted chiefly of groundsel (*Senecio vulgaris*), annual meadow grass (*Poa annua*), chickweed (*Stellaria media*), and corn spurrey (*Spergula arvensis*). The relative effectiveness of the various treatments to weeds can be gauged from the following table, which shows the total live weed numbers per 1½ square feet of seedbed, four weeks after spraying.

NUMBER OF LIVE WEEDS PER 1½ SQUARE FEET OF SEEDBED, FOUR WEEKS AFTER TREATMENT WITH THREE SUBSTANCES AT VARIOUS CONCENTRATIONS

Table 3

M C.P.A.		D.N.O.C.		VARSOL		UNTREATED
0.075%	21.0	0.45%	18.0	50 mls. per sq. yd.	8.8	
0.15%	12.0	0.6%	9.0	70 mls. per sq. yd.	9.0	37
0.30%	12.0	0.8%	9.0	100 mls. per sq. yd.	6.0	
All at 100 mls. per sq. yd.	All at 100 mls. per sq. yd.					

The most satisfactory weed control was given by Varsol, which was also found to be the least damaging to the tree seedlings. The mortality caused by these weedkiller treatments among the seedlings of the tree species tested is, however, still found to be too high to permit their use on a practical scale, (a possible exception is the pines which appear to be more resistant). Tests are now being made of a wide range of mineral spirits and oils, in an attempt to discover a compound with a sufficiently high degree of selectivity in its toxic effect as between conifer seedlings and herbaceous weeds to permit of its being used safely on a large scale.

All the results mentioned above refer to experiments in which only a single spray application was made during the growing season. Experiments in which spray applications were repeated as required by the development of the weed crop, showed that almost complete weed control is possible with Varsol and with Tractor Vaporising Oil. The repeated application of M.C.P.A., D.N.O.C. and Tractor Vaporising Oil causes heavy deaths in all tree species (vide Table 4 for Sitka spruce). Varsol, however, is less damaging to most of the spruces, and has no appreciable effect on Corsican pine and Scots pine (e.g., column 5 in Table 4).

NUMBER OF HEALTHY TREES PER 1½ SQUARE FEET OF SEEDBED, AFTER VARIOUS WEEDKILLER TREATMENTS

Table 4

Treatment	Sitka Spruce				Scots Pine
	Before 1st spray 25/5/49 (1)	14 days after 1st spray 13/6/49 (2)	14 days after 2nd spray 28/6/49 (3)	14 days after 3rd spray 11/7/49 (4)	14 days after 3rd spray 11/7/49 (5)
M.C.P.A.	1	92	23	19	8
D.N.O.C.	1	109	0	1	3
VARSOL	2	121	85	50	35
T.V.O.	1	166	14	1	4
Untreated	0	151	149	155	35

Considerable selectivity is shown in the action of varsol on pines and annual weeds, and satisfactory weed control is possible by this means.

Use of Benzene Hexachloride (B.H.C.) Compounds for Protection of Seedlings and Transplants Against Damage by Chafer Larvae

Treatment of Seedbeds

Experiments were commenced in 1947 and 1948 with the object of assessing the value of B.H.C. insecticide for the protection of seedlings and transplants against damage by chafer larvae and other root-feeding insects in forest nurseries. Published accounts of experiments with B.H.C. on cereal crops indicate that the substance possesses toxic properties which can depress seed germination or retard root development of the crop plant. A preliminary experiment was accordingly carried out at Rhinefield Nursery, New Forest, in 1948, to test the possible phytotoxic effect of B.H.C. application to seedbeds of Japanese larch. The results of this experiment showed conclusively that concentration of B.H.C. dust in the region of the seed at the time of sowing causes a pronounced depression of germination and growth. This toxic effect was most apparent in those treatments where the dust was placed in direct contact with the seed at the time of sowing in drills. Broadcast application to the seedbed surface prior to sowing caused lower mortality, but here also all application rates tested, ranging from 2 oz. to 8 oz. per square yard of 3.5% benzene hexa-chloride, caused high seedling losses.

It is known that a high percentage of residual B.H.C. can be recovered from treated soil up to two years after application. In order to test the importance, and possible danger of this residual effect on subsequent crops a seedbed experiment was laid down in 1949, on ground which had received 3.5% B.H.C. applications at 1 oz., 2 oz., and 3 oz. per square yard in 1947. No applications were made subsequent to this. A test of the residual effect in 1949 on seedbeds of Sitka spruce, Japanese larch, and Scots pine showed a reduction of chafer damage, with an appreciable increase of seedling growth and stocking by all B.H.C. treatment residues

It seems evident that the residues two years after treatment are still sufficient to act as an insect repellent and to produce appreciable increases of seedling survival. It was clear from the results obtained at Rhinefield in 1948, that the use of B.H.C. dust on seedbeds in the year of sowing, is damaging to seedlings even at the lowest application rate tested (2 oz., 3.5% B.H.C. per square yard). A range of lighter applications to seedbeds was tested during 1949 at Hemsted Nursery, Kent, and Ringwood Nursery, New Forest. The applications, which were applied broadcast to the beds prior to sowing, ranged from 2 oz. per square yard 3.5% B.H.C. to 1 oz. per square yard of a preparation containing 0.9% B.H.C. None of these applications adversely affected seedling growth, but in the case of Douglas fir and Japanese larch, there were fewer seedlings with the heaviest application rate. At both nurseries it was found safe to apply B.H.C., prior to sowing, at concentrations up to 1 oz. per square yard, (approximately 3 cwt. per acre, 3.5% B.H.C.) without damage to the one-year seedlings of Douglas fir, Japanese larch, Scots pine, Sitka spruce, and beech. It is advisable to rake the substances well into the soil before sowing the seed. From experiments carried out in 1947 on an area with a heavy chafer infestation, it was found that the heaviest safe application of 3 cwt. per acre referred to above, was highly effective in reducing insect activity.

Treatment of Transplants

Experiments carried out up to the end of 1948, indicated that the use of 3.5% B.H.C. dust, to protect transplants of Sitka spruce against cockchafer damage, was most effective. The B.H.C. was applied either mixed with the soil before lining out, at 4 lb. per 1,000 plants, or as a dust dressing of the

roots of the plants immediately before lining out. Both these methods of application were equally effective in reducing chafer damage.

Further tests were made at Hemsted to compare more critically different techniques of application, and their effect on transplants of a range of species. Dressings of B.H.C. mixed into the soil to a spade's depth, at rates ranging from 2 oz., 3.5% B.H.C. per square yard to 1 oz., 0.9% B.H.C. per square yard, produced no damaging effects on transplants of Sitka spruce, Douglas fir, European larch, Scots pine or beech. These dressings were applied immediately before lining-out. At Hemsted, where there was a mild chafer attack, there was an appreciable increase in the outturn of healthy one-plus-one transplants as a result of treatment. There is no appreciable difference between 2 oz. and 1 oz., 3.5% B.H.C. in this respect, and the latter is to be recommended.

B.H.C. treatment by direct applications as a dust to the roots caused considerable damage to the plants in many instances. 3.5% B.H.C., and a stronger concentration, were both particularly toxic.

2% B.H.C. causes only slight damage, but European larch and Douglas fir plants are sensitive even to the lightest dressing. Thus while root-dusting appears as effective as soil dressing in chafer control, the direct phyto-toxic effect of the concentration of dust in the vicinity of the roots, eliminates it as a practical technique. The most satisfactory treatment for Douglas fir transplants is 3.5% B.H.C., applied to the soil at 1 oz. per square yard, before lining-out.

Grading of Seedlings for Lining-out or Planting

The Effect of Height and Diameter on Growth and Survival

The practice of grading seedlings prior to lining-out or dispatch for planting, is common to most forest nurseries. The actual technique and basis of the grading has varied from one nursery to another, but nearly all methods involve sorting on a height basis, all plants above a certain arbitrary minimum height being classified as "usables". Further grading may take place within the "usable" seedling category, rejecting diseased, malformed or weakly plants. In order to test the meaning of variation in seedling size at the time of planting in terms of subsequent performance and vigour, carefully graded stock was planted out in two experiments in 1949. A stock of two-year seedlings of Sitka spruce was graded into one-inch height-classes, and millimetre diameter-classes, and part of this graded stock was lined-out under normal nursery conditions in the spring of 1949. The seedlings graded covered a range of height of one inch to ten inches. The percentage survivals in the various height classes after one year were not significantly different, although the smallest class (one to two inches) showed an appreciably lower survival percentage than larger sizes. No one height-class showed greater vigour than another. Variation in diameter within each height-class had no effect on plant survival or vigour of growth. It is clear that under good cultural conditions in the nursery, grading of seedlings for lining-out is not very important except for rejection of plants which are too small to handle.

A second set of graded two-year Sitka spruce plants which was planted out on deep single-furrow ploughing on an exposed site at St. Gwynno Forest, South Wales, showed definite differences in vigour and survival rate of plants in relation to their height and diameter at the time of planting (vide Table 5).

As for the lining-out test, the plants in the various height-classes show similar growth proportional to their heights at the time of planting. Any height advantage at the time of planting is retained after one year in the forest. Seedling survival, however, varies considerably from one size-class to another.

EFFECT OF SIZE OF PLANT AT TIME OF PLANTING ON GROWTH AND SURVIVAL OF SITKA SPRUCE

Table 5

Size at Planting, March, 1949		Plant Assessment, November, 1949	
Height Class inches	Diameter Class in millimetres	Mean Height inches	Death percentage
1–3	0 — ½	2.65	61.67
	½—1½	3.79	30.0
4–6	0 — ½	4.00	56.67
	½—1½	5.67	23.33
	1½—2½	6.47	18.33
	2½—3½	6.19	13.89
7–9	½—1½	7.46	16.67
	1½—2½	8.29	10.0
	2½—3½	9.29	6.67
	3½—4½	9.20	6.67
10–12	½—1½	9.7	44.44
	1½—2½	9.88	16.67
	2½—3½	10.33	3.33
	3½—4½	11.54	8.33
	4½—5½	12.05	6.67
Over 12	1½—2½	11.33	30.00
	2½—3½	13.16	26.67
	3½—4½	13.23	10.00
	4½—5½	14.93	3.34

It can be seen from the table that while there is an increase in survival rate with the greater height of the seedling at planting, the survival is actually very much more dependent on general sturdiness of the plants as expressed by diameter, and by the proportion between height and diameter. The use of taller plants for planting has little effect on survival rates, unless increased height is accompanied by a proportional increase of diameter.

Season and Date of Lining-out of Seedlings

Following the successful results of summer lining-out of Scots pine in 1948, in Conservancy nurseries in the North of Scotland, an experiment was started to see how far the lining-out period could normally be extended. One-year heathland seedlings of Scots pine, Sitka and Norway spruces, and European larch were used. Lining-out commenced in August, following a summer drought unusually severe in some nurseries. In some cases the results were not unnaturally very poor, but in others the plants, though not putting on shoot growth, survive, and have probably started root development. Seedlings lined out later in September-October suffered variously. At Inchnacardoch most were thrown out by frost-lift. The late autumn and spring (November and March) plants were the largest of all when transplanted, and usually survived, but it is possible that the small plants which were lined-out in August and September will now catch them up, as they appear to be well established. Considering that the seedlings were all one year old, the results are better than might have been expected.

Miscellaneous

Vegetative Propagation

Raising of cuttings taken from early- and late-flushing spruce trees was again carried out by the Royal Botanic Garden, Edinburgh, on our behalf. As the cuttings of the previous year, taken from side shoots, did not always grow straight, this year terminal and side cuttings were taken separately.

The cuttings from the early- and late-flushing plants tended to reproduce these habits in the second year when lined-out.

Special Intensive Methods

A trial was made to determine how far the production of large one year seedlings of Sitka spruce could be improved by raising them under glass in lightly-constructed cold frames fitted over standard seedbeds. Several glass treatments were tried. In all cases the crop response to glass treatment was almost negligible. There is, however, a strong indication that the incidental side shelter effect of the sides of the cold frame was responsible for considerable growth increases.

Experimental Technique

The coefficient of variability (ratio of the standard error per plot to the mean of the experiment) has been reduced during the year. This is attributed mainly to the carrying out of nursery operations block by block instead of treatment by treatment, as frequently happened in the past, and to the use of different layouts designed to suit each individual nursery.

NURSERY EXTENSION EXPERIMENTS AT RADNOR FOREST

By R. D. PINCHIN
Assistant Silviculturist

The history of this series of experiments dates back to the period 1921 to 1927, when a comprehensive range of experiments designed to test various nursery practices was carried out at different nurseries in Britain by the Commission's Research Officers. The results of these experiments were published in *Nursery Investigations*, Forestry Commission Bulletin No. 11, by H. M. Steven (1928). It was decided in 1928 to extend into the forest certain of the experiments which formed part of these investigations, and altogether some sixteen experiments were so dealt with.

Performance of plants in the forest is the final test of nursery practice. While methods and conditions in our nurseries have changed considerably since Bulletin No. 11 was published, there is still some interest in the results of these extension experiments.

Forest Site

The site selected for planting these nursery extension experiments was in Radnor Forest in the Welsh Marches, on fairly uniform ground within a range of elevation of 1,200 to 1,466 feet. Most of the experiments were laid down in 1928, in one large block on the northern side of Ednol Hill on a moderate to gentle slope, with an aspect varying from north to east.

The geology of the region is Silurian, and the brown earth soil profile over this large experimental area shows little variation. It consists generally of two or three inches of bracken-bilberry peat overlying seven or eight inches of fertile brown loam, becoming clayey and shaley with depth. At the time of planting a mixed vegetation of grasses and bracken dominated the area, with bilberry abundant locally. Climatic conditions would not be rated severe, the mean annual rainfall being in the neighbourhood of forty-five inches, while exposure to the prevailing wind is only moderate.

A layout consisting of four replications arranged in randomised blocks was generally adopted.

Periodical assessments were carried out until the eighth growing season, and the most important of these have been statistically analysed to test the significance of any considerable differences in growth and losses due to the various treatments at the nursery stage, or to the effect of grading into good plants and culls at the time of planting. The main results of these analyses are summarised below under the various subjects of experiment.

Method and Density of Sowing

A series of four experiments to compare broadcast and drill sowing of seed at four different densities was carried out at Bagley Nursery, Oxford (Expt. No. 4, 1925 and 1927), with the following species: Douglas fir, European larch (two experiments) and Sitka spruce. For the first two species the sowing densities were, in square feet per lb. of seed: broadcast sown—300, 150, 100 and 50; drill sown—450, 300, 200 and 100. The densities for Sitka spruce were: broadcast sown—600, 450, 300 and 150; drill sown—900, 600, 400 and 200. It should be pointed out that improved seedbed practice has considerably decreased the sowing density required for a given out-turn of plants since these experiments were carried out.

After two years in the seedbeds, the stock was lined-out for one year, and on planting out in the forest the plants were graded into good plants and culls. Except where otherwise stated, the expression "cull" is used in the wide sense, to include (1) weakly plants, spindly and poorly furnished, (2) deformed plants without a leader. The term is very unscientific, lumping indiscriminately the effects of heredity, overcrowding and mere damage.

Losses on Establishment

There were no significant differences in losses on establishment due to the effect of different sowing densities, nor between the broadcast and drill sown treatments, all such effects being evened out by a year in the lines, as might be expected.

Overall losses of culls (34.3%) were, however, much higher than the losses of good plants (16.7%) over the four experiments at the end of the third season. This difference is significant at the one per cent. level of probability.

Losses among the good plants were, on the whole, slight, except in the case of Douglas fir which averaged 27.5%.

Height growth

Height growth at the end of the eighth growing season showed that there were no significant differences in mean height resulting from the different densities or methods of sowing at the nursery stage.

There was, however, a considerable difference shown between the mean height of good plants (68.8 inches) and the culls (53.1 inches) taken overall, the good plants being taller by an average of 15.7 inches over the four experiments. This difference is significant at the one per cent. level of probability.

Analysis of the data shows that the different densities and methods of sowing in the nursery bore no significant relation to the differences in growth and losses between good plants and culls when planted out in the forest.

Spacing of Transplants

The investigation into the effect of using different spacing distances in the nursery transplant lines was carried one stage further in 1928, when stock raised at various spacing distances was put out in the forest. This series comprises six experiments using the following species: Norway spruce (two experiments), Sitka spruce (two experiments), European larch and Douglas fir, the transplant spacings were 1 in., 1½ in., 2 in., and 3 in., in the rows by 10 in. between the rows. The plants were graded in the forest into good plants and culls.

Losses on establishment

In this series of experiments, losses among the spruces during the first three years were slight, whereas the losses of European larch and Douglas fir were considerable (losses of good plants 32.3% and 25.4% respectively).

Comparing the effect of the different spacings on losses among good plants in the first three years, it is noted that the narrower spacings tended to produce a higher percentage of deaths than the wide spacing, though not significantly so (Expts. No. 12 European larch and No. 22 Norway spruce).

Overall losses among the culls in this series were 24.0% compared with 11.1% among the good plants. In three of the experiments the difference was significant at the one per cent. level of probability.

Height growth

The spacing experiments have emphasised rather strongly the lack of response in height growth to different spacing distances used in the transplant lines. On the whole, the height differences recorded are small and insignificant throughout the series. It is again brought out, however, that the good plants grow at a much faster rate than the culls, showing, after 8 years, a mean height of 72.2 inches as compared with 56.9 inches over the whole series. The difference of 15.3 inches is significant at the one per cent. level of probability.

Grading of Seedlings

A large-scale nursery grading experiment using the species Sitka spruce (two experiments), Norway spruce (two experiments) European larch and Douglas fir, which was carried out in 1926, was extended into the forest in 1928. The three grades into which the seedlings were classified at the time of transplanting were:—

1. Seedlings over one half the maximum shoot length,
2. Seedlings less than half the maximum shoot length.
3. all badly rooted, diseased, supressed, drawn, weakly and damaged Seedlings irrespective of size.

An additional class combining grades 1 and 2 was also used. On planting out in the forest after two years in the lines, each of the four treatments was further divided into good plants and culls.

Losses on establishment

In the four experiments using Sitka and Norway spruce losses in the first three years were negligible, but in the two experiments using Douglas fir and European larch the overall mean losses were considerable, being 45.1% and

22.8% respectively. These losses would appear to reflect the unsuitability of the site for the two latter species, particularly as regards elevation and exposure.

Losses occurring at planting were shown by these six experiments not to bear any significant relation to the different gradings carried out at the seedbed stage.

The final forest grading into good plants and culls has, however, provided conclusive results. In the Douglas fir and European larch experiments in which losses were appreciable, the overall losses among the culls were 12.0% and 24.9% respectively, higher than among the good plants. These differences are significant at the one per cent. level of probability. In addition, three of the four spruce experiments show overall cull losses which are significantly higher at the five per cent. level.

Height growth

One of the outstanding results of this series of experiments was the fact that only very small and insignificant differences in height were shown by the plants in their eighth year as a result of the nursery grading at the time of lifting from the seedbeds.

On the other hand, it is remarkable that in all six experiments the final forest grading, i.e., into good plants and culls, produced conclusive results. The mean height for all the good plants was 60.6 inches compared with only 48.0 inches for the culls, a difference of 12.6 inches, which is significant at the one per cent. level of probability.

The results of the grading experiments point to the conclusion that seedbed performance does not give an easy guide to the ultimate behaviour of the plant under forest conditions. Later, at the time of planting out in the forest, a simple grading into good plants and culls will more consistently forecast growth and general behaviour.

EXPERIMENTS IN PLANTING ON UPLAND HEATHS

By J. W. L. ZEHETMAYR

Assistant Silviculturist

On the east side of Scotland and northern England there are large areas of heath with characteristic *Calluna* vegetation overlying a podsolised soil. The natural or semi-natural tree vegetation of the heaths is Scots pine, but the crop rarely forms more than scrub. A somewhat arbitrary distinction has been drawn between peat and heath according to the form of the raw humus. The heaths are defined as areas where the organic layer is generally less than three inches thick and formed chiefly of *Calluna* raw humus, while in the peatlands the organic layer is generally deeper, but it may be thin and it is always moist.

The Forestry Commission has acquired a considerable amount of land on these heaths, and a number of experimental centres have been developed to provide information to facilitate the task of afforestation; the most important are in the Allerston group of forests on the Yorkshire moors and at Teindland forest in Morayshire. (A large number of valuable trials at the latter were unfortunately lost in a fire in 1942.) Other groups of experiments are in the

Black Isle (Ross-shire), at Clashindarroch (Aberdeenshire) and at Hamsterley (Durham). In all about 290, or 25%, of the forest experiments in the northern half of Great Britain lie on these poor heaths. The main subjects covered are: (a) soil preparation, which has proved to be most important for obtaining quick establishment; (b) species trials; (c) methods of introducing more valuable species into the more easily-grown pines. These trials are not at the present stage easily separable from those dealing with: (d) species mixtures; (e) manuring; (f) types of planting stock, and (g) direct sowings. Some subjects such as provenance and field extensions of nursery experiments are also under investigation; but these are more satisfactorily reviewed on a wider basis than when confined to the experiments on the heaths alone.

As the survey of the peat experiments neared completion in the summer of 1948, preparation for a similar survey and summary of the heathland experiments commenced. Profiting from the lessons learned in the earlier task, the following procedure was adopted and the progress made is shown below.

Review of Assessment Methods

Laborious 100%, 50% or similar assessments have been the rule for many years. After a visit to the Allerston experiments it was realised that no rigid sampling method could be applied owing to the extreme variation of layout and unit size, and of the matters to be investigated. A flexible system was worked out based on the following rules:—

(*a*) For any stand in which canopy is closed, or about to close, a "top height" is obtained, based on the measurement of a constant number of trees per unit area, each tree measured being the largest in its sampling unit.

(*b*) For younger plantations line surveys are made at random, usually a minimum of two per plot being imposed, so that the precision of the sample may be estimated.

The vast majority of the experiments deal with establishment problems and are under twenty years old; thus height growth and survival are practically the only criteria used in assessing. A considerable saving of time has been achieved by these methods, and as results have been consistent and satisfactory the methods have been generally adopted.

The assessing in the forest was completed early in 1949, as under:—

Forest	*No. of experiments assessed*	
Teindland	17	127 in all. The remaining experiments are either too young, have been destroyed, or have completed their useful life.
Clashindarroch	19	
Allerston .... Wykeham	32	
Allerston .... Broxa	19	
Allerston .... Harwood Dale	20	
Hamsterley	10	
Other Forests	10	

Statistical analyses have been carried out wherever possible and the results of the more important experiments have been set out diagramatically by histograms. Field reports on the condition of the trees and other points of interest have been made for the majority of the experiments by the Research Foresters or Assistant Silviculturists.

Summaries of the Experiments

The results of each experiment from the time of planting have next to be set out, and a start has been made in drafting reports, nearly fifty having been

completed. In some cases these reports will be the final ones on older experiments which have now fulfilled their original purpose. Simultaneously with the final working up of the experiments, it is hoped to place the essential information in a card index grouped under the International Decimal Subject Index. The vast majority of the work remaining is compilation, and it must be carried out in the office rather than in the forest, though numerous questions are bound to arise when the results start to be pieced together which will only be answered by re-investigation in the forest.

It is possible to review very briefly the major points which have emerged from the work on these heaths.

Method of Ground Preparation

Ploughing was practicable far earlier on the heaths than on the peatland, and the first experiments were laid down in 1924. Moderately deep ploughing (eight to nine inches) has been shown to be superior to shallow (four to six inches). Subsoilers running below the plough have been shown to increase growth slightly. There is also an improvement in growth rate as the number of furrows turned per row of trees is increased from one to two, two to three, and then to complete ploughing—the financial aspect limits practice here, however. A change to deep single-furrow ploughing (twelve to sixteen inches) using the "R.L.R." plough was made in 1943; but the experiments laid down then have, as yet, given no clear result as to its value compared to other methods, though its adoption as a general Forestry Commission practice is justified as an improvement over the single shallow furrow with subsoiling, in use for some years previously. Certainly there is room for further experimentation to fill in gaps in the evidence, and to try out other methods of ploughing and possible alternatives to ploughing. One difficulty is that the factors which are modified by ploughing have not yet been isolated to discover the real importance of each one. This problem is now being investigated by research workers attached to the Imperial Forestry Institute at Oxford. The experiments have repeatedly demonstrated, however, that removal of competition from heather is one of the major factors in the response of trees to ploughing; and subsequent re-invasion of the plough furrows by heather is often accompanied by checking of the trees.

Species

Pines grow well planted pure on the heaths, but practically the only other species of which this can be said are Japanese and hybrid larches, which are generally the fastest growing species on ploughed land. Other species will grow well only when nursed, and are therefore dealt with below.

Nurse crops and Mixtures

As mentioned above, these two subjects can hardly at present be separated, since none of the nursing experiments have reached the stage where removal of the nurses can be considered. The methods employed for trials of more valuable species, in particular Sitka spruce, are (*a*) planting with a nurse at time of afforestation, (b) introduction later among established pines six to ten years old, (c) underplanting, (d) nursing by legumes, chiefly broom. Good results have been obtained in the short period during which the experiments have run. To date the most rapid growth of the more difficult species has been attained at Teindland by introduction into ten year old *Pinus contorta*, and at Broxa (Allerston Forest) by use of broom as a nurse. Species showing promise are, Douglas fir and Tsuga, but many other species have done well on ploughed ground with broom. Beech, Lawson cypress and silver firs, which when originally tried about 1930 never grew at all, are all promising where broom was sown on R.L.R. ploughing.

Thus, although all the experiments are very young, there is every hope that the pine forest, originally the only possibility on the site, may be varied by admixture with other species, including some hardwoods. Among the latter, the role of birch is of particular interest in view of the great importance attached to it by Scandinavian foresters, and this matter is also one being investigated by the Imperial Forestry Institute workers from the fundamental point of view. It is also possible that some of the conifers, such as Douglas fir, may be found to be soil improving species, and this hope is not being overlooked.

Manuring

On this subject very much less work has been done on the heaths than on the peatlands. While phosphates are essential to good early growth of more difficult species, the effect on pines is usually only to give a quicker start and thus a lead of a few feet, which although it persists for many years, does not make manuring an economic proposition. On the poorest heather ground, however, the effect even on pines is greater, and in a *Pinus contorta* stand planted in 1928 at Teindland the effects of basic slag applied at that time are still clear both in height growth and foliage colour. Therefore on the poorest heaths phosphates should be applied even to pines. Recently, nitrogenous manures have been shown to be of great value in trials of direct sowing in Yorkshire.

Other work

A large number of trials of types of planting stock have been made, and have generally brought out the superiority of plants from heathland nurseries for use on the heathland sites. Many extensions of special nursery treatments have been planted out in the forests; much work on parallel lines has been done in Yorkshire for the Sub-Committee on Nutrition Problems in Forest Nursery. There have also been trials of Dr. Anderson's method of group planting, of shelter belt planting and, before ploughing was universally adopted, of methods of direct planting and ground preparation.

Recent work on the heaths has dealt with direct sowing, the use of large one-year seedlings, and the position of planting on ploughed ground; results may be briefly summarised:—

Direct sowing

Results have been very satisfactory in Yorkshire with both Scots pine and Sitka spruce, where a complete N.P.K. fertiliser was given; many seedlings have reached one foot in height in three years from sowing. The droughts of 1949 led to rather poorer results with these species, and with others being tried for the first time. Late and early frosts have prevented any such results being obtained on the heavier soils of the Black Isle of Ross-shire.

One-year seedlings

In 1946, planting started with one-year seedlings of Sitka spruce raised with compost in the new heathland nurseries, or with partial sterilisation by steam or formalin in the old established nurseries. The earliest plantings grew extraordinarily well, but some of the later experiments have suffered severe losses, as at Teindland in 1947 where late plantings after the severe winter suffered very

heavy losses in the succeeding drought. Losses in 1948 were much lower, but were high enough to point the need for very careful choice of sites for one-year seedlings. Clearly, handling, transport and planting need to be more carefully organised than with transplants, since the seedlings do not possess the latter's powers of recovery. Even so the cost of afforestation with seedlings followed by beating-up with even 30% of transplants is likely to be lower than initial planting with transplants. After the additional experience of one or two more seasons, it will be possible to review the capabilities of seedlings on the heaths.

Position of planting

Sitka spruce of various ages has been planted in a number of positions on the ridge and furrow of deep R.L.R. ploughing. To date, all results indicate that on the drier heaths the furrow bottom position is the most satisfactory for survival and growth in the early years. The oldest experiment of this series at Allerston contains Scots pine in addition, and is now five years old. A further period of years must elapse before it can be seen whether this effect persists, but these experiments raise interesting questions as to the function of ploughing. Ploughing removes the heather competition, breaks the pan, and provides early shelter; but the first purpose would normally be said to be cultivation. If planting is in the furrow bottom, practically no benefit can be obtained from the cultivation of any depth below the point of planting, and the question arises as to what is the real function of the ploughing. Ploughing probably has a multiple function in this instance, in which nearness to a damper stratum, shelter, and removal from the toxic influence of *Calluna* play important parts.

Hamsterley Experiment Report

A detailed report on the ten experiments at Hamsterley testing methods of afforestation of upland heaths was submitted. This forest is in south-west Durham and the experiments form an outlier to the main concentration at Allerston. They were laid down in two groups, the first in 1929-30, the second in 1938-40. In the intervening period ploughing had been developed, and the effect of this is well demonstrated by the fact that the crops in the newer experiments are now, in many cases, as advanced as those in the older series.

All the experiments have suffered severely from damage by various agencies, the earlier group from black game, the late ones from sheep during the war, when maintenance of fences was almost impossible. The results confirm those at Allerston, and as such they are covered by the review given above. There was, however, one interesting additional result; caging of Scots pine against black game from 1930 to 1937 had led to a fifty per cent. increase in height at the present time, thus illustrating the severe attack to which the pine were subjected in this area during those years.

History of the Allerston Experiments

A brief review of the experiments in this area was produced for use in a general history of Allerston Forest. While again it covers much the same ground as the summary given above, it combines the historical aspect with a review of progress by subjects. Thus the importance of some of the experiments to the whole development of the Allerston area is emphasized. A good example is the early ploughing experiment (Wykeham 6. P.28) which demonstrated conclusively the value of ploughing compared to direct planting methods. The experiments demonstrated as early as 1938 the possibility that spruce might be nursed into growth by pine or larch, and this led to a great variety of experiments on methods of nursing and to the use of spruce on a considerable scale in the forest. The early trials of heathland nurseries have also recently

borne fruit in the great extension of these nurseries in general Forestry Commission practice. This special review should be of value to members of the Forestry Commission staff who wish to know something of the basis upon which current practice in this area has been built, and to avoid such pitfalls as have already been encountered by their predecessors.

Report on Sitka spruce at Clashindarroch Forest

Considerable anxiety has been caused by the failure of spruces to grow on heather-clad areas at Clashindarroch Forest, Aberdeenshire. Following an inspection by the Chairman of the Forestry Commission, the Research staff were instructed to investigate the rates of growth of the different species under different conditions and to make recommendations for future treatment.

The procedure adopted was to search for areas of the main species which had been planted by various methods on comparable ground, both in Conservancy and Research areas. By sampling and measuring the previous annual shoots, the height and growth rate were ascertained, and age-height curves prepared for each crop. Fifteen years was selected as an age at which the effect of the site and planting methods would have become apparent, and the actual or predicted height at this age was recorded. A very condensed summary of the results is given in Table 6 below.

MEAN HEIGHTS AT FIFTEEN YEARS OF VARIOUS SPECIES UNDER DIFFERENT CONDITIONS OF PLANTING ON HEATHLAND AT CLASHINDARROCH FOREST

Table 6 Feet

Species	Unploughable ground. Direct planting	Ploughable ground		Single furrow shallow ploughing	Double furrow ploughing	Complete ploughing
		Direct planting	Turf planting			
Contorta pine	–	5–13	6	8–10	14	15
Scots pine	–	3½	–	7–13	14	10–15
Sitka spruce mixed with Scots pine	–	–	–	3–10	11	8–14
Sitka spruce pure	1–2	1–3	2½–3	4–5	–	6
Norway spruce	2½	2–3	–	–	–	–
European larch	8½	12	–	–	–	–
Japanese larch....	14	7½–17	–	–	–	15
Hybrid larch	17	–	–	–	–	–

The figures represent the mean heights of varying numbers of crops and are rarely directly comparable; it was not possible to find all combinations of treatment and species. The main conclusions drawn from the data were:—

(*a*) Direct planting gives very poor results with all species except Japanese and hybrid larches, and in some cases contorta pine. Scots pine, as well as both spruces, are extremely poor when directly planted on such difficult heathland.

(*b*) Turf planting, for which there is only limited scope at Clashindarroch, gave little better growth.

(*c*) Single-furrow ploughing has doubled the growth of Scots pine and Sitka spruce, and where the two are in mixture the growth of the spruce

may be doubled again. In certain areas where pine had been introduced on plough furrows into checked spruce, a real improvement had taken place in the growth of the latter.

(*d*) Increased ploughing intensity further improves growth; particularly of spruce when in mixture with pine.

The main recommendations were divided into "general" and "salvage". The general section discussed the method of treatment for new planting areas on heather ground, pointing out the inadvisability of using pure spruce on such areas even after ploughing; the good promise of Japanese and hybrid larch on unploughable ground; and the possibility that spruce can be grown in mixture where more intensive cultivation is possible.

As regards salvage methods for the checked areas at Clashindarroch, the report recommended that in areas where steepness or boulders made ploughing impossible, the existing badly checked spruce should be liberally interplanted with larches. Where ploughing is possible, then belts of furrows, or closely spaced single furrows, should be made and planted with pine or larch.

PLANTATIONS ON PEATLANDS

By J. A. B. MACDONALD
Silviculturist, North

The Peatlands

The north-western highlands and the Border hills are the two main peatland regions; in both the covering of blanket bog resulting from a wet and cloudy climate and more or less acid rock or glacial debris has been increased in recent centuries by scrub clearance, sheep grazing and moor burning. It covers the greater portion of the landscape. Naturally the surface peat varies in character; over the more basic rocks of the Cheviots—the White Hill Lands—the herbage is mainly the grass *Molinia caerulea* which when bleached white in winter gives the lands their name. This region has, as a rule, a foot or so of black crumbly peat formed by *Molinia* remains, but there are in places much more difficult types on occasional high moors and on sites where drainage is locally impeded. In the West Highland area where deer grass, *Scirpus caespitosus*, dominates the herbage at least for ten to twenty years after burning, the resulting peat is tough, acid and intractable.

In the 1949 Research Annual Report, the experiments on peat types were dealt with comprehensively, and the fact that a bulletin was in preparation was announced; work on the bulletin is now well advanced. This year, therefore, only a few more or less new points of importance connected with the peat project are mentioned.

Forest draining and drain maintenance, and the problems of stability on the Border Peatlands

It was in the large plantation known as Moorburnhead, on the Buccleuch Estates near Canonbie on the eastern boundary of Dumfriesshire, planted—mainly with spruces—some thirty-five years ago on typical white-hill land, that attention was first directed to the very special dangers this type of land holds. At the time of planting comparatively few drains were opened on the shallow

Molinia peatlands at Moorburnhead, and for many years the drains received no attention. As a result, litter began to choke them, water overflowed here and there, and generally the water table rose to within an inch or two of the surface both on the flats and on some of the more gentle slopes. Towards the end of the War, (i.e., about 1945) wind laid flat some acres of the plantation, and since then the damage has spread almost annually.

Although much shallow draining has been done in the more recently planted parts of the nearby Forestry Commission unit, Newcastleton Forest, since turf planting was introduced, several of the first year's plantings there (from 1920 onwards) had, as at Moorburnhead, been directly notched. In some of these areas, where drains were few, it was not therefore surprising to find the water table was much too near the surface and that stability of the trees, many of which were growing fast, was endangered. Actually, within a month or two of this being reported, a few acres of Newcastleton Forest were uprooted by wind.

The need for experimental information was felt acutely, as there was relatively little to be extracted from the Forestry Commission's few existing draining experiments which were, unfortunately, on other ground types. The general indication provided by these experiments is that growth of trees improves with the intensity of the draining, at least for the first fifteen years after planting; as will be seen from Table 7 below, both distance apart and depth of drain gave responses.

HEIGHT GROWTH OF TREES
PLANTED ON GROUND GIVEN VARIOUS DRAINING TREATMENTS

Table 7 Measured in feet, fifteen years after planting

Forest	Species	Type of Drain and Distance apart in feet				
		Shallow, 7 inches deep	Ordinary, 15 to 18 inches deep		Deep, 30 inches deep	
		at 8ft. apart	at 30ft. apart	at 10ft. apart	at 30ft. apart	at 10ft. apart
Glen Righ, Inverness-shire (Expt. 33, P. 36)	Contorta pine	10	14.6	14.0	14.8	15.2
	Japanese larch	9.1	14.0	14.0	14.0	16.9
	Sitka spruce	5.0	6.1	5.1	5.2	5.8
Forest of Ae, Dumfriesshire .... (Expt. 8, P. 36)	Contorta pine	9.6	10.6	10.7	13.2	14.9
	Japanese larch	4.7	6.6	6.4	12.1	12.3
	Sitka spruce	6.7	8.6	8.5	10.8	11.0

In order to obtain some essential basic information before laying down long-term draining experiments, sets of preliminary trials were established in July, 1949, at Kielder Forest, Northumberland (54, P.49), and Newcastleton Forest, Roxburghshire (12, P.49). Test wells were opened to study the movement of the water table in different plots, which were subjected to different depths of drain deepening. Results were recorded over a period of months during which varying weather conditions were experienced. Levels in the test wells have shown that a very real lowering of the water table is attained within a short period by deepening drains to 30 inches; under such conditions, while the water table may reach the surface during very wet periods, the depth of the water at other times is generally 50 per cent. lower than in the plots

where the untouched drains had a depth of not more than one foot. Over the greater part of the year, therefore, a considerable increase in the volume of soil is provided for free rooting. That deepening does lower the water table in those rather clayey Border soils is therefore established, and the initial degree of lowering can be stated. The next step is to find out just what effect this has upon rooting depth, tree growth and stability.

It is proposed first to test the degree of stability of trees standing on sites with varying levels of water table, by measuring the pull required to uproot sample trees. Since stability must be determined not only by the ground moisture conditions but by the degree of thinning to which the wood has been subjected, the long term draining experiments which it is now proposed to lay down will include four degrees of thinning in addition to three intensities of draining.

Trial Plantations on High-lying Peat Areas

The higher level peat areas in Kielder Forest, Northumberland, where *Calluna* tends to be dominant over *Molinia*, are usually considered unsuitable for planting. In order to determine whether economic plantations can be raised on such sites, trial plantations have been laid down using the best known methods of ground preparation. As a matrix over the greater part of the area, the species believed to be the best for the site is planted. Other species chosen as being hopeful, but less certain, are inserted as groups throughout the area within the main species. Every likely species is thus included, and all plants are given all possible encouragement to grow by manuring and other means. It is hoped that the shelter and *Calluna* suppression provided by the matrix species will create conditions favourable to the growth of spruces and other species which could not be expected to grow pure on such sites.

Caithness and Sutherland

Pilot plantations of the above type were laid down during the year in an area at Skiall near Thurso, Caithness, on a type of land which, although on a different formation, is not very different from some of the Border country, except for its proximity to the stormy Pentland Firth. The whole region is noted for its high and constant winds, which seem to blow mainly from the north-north-west. Peat is present only on the upper part of the Skiall area, but the main slopes are on a stiff clay loam. The scheme of planting outlined in the previous paragraph was employed at Skiall, the main matrix species being Sitka spruce. Altogether eleven secondary species, including mountain, contorta, Corsican, Scots and maritime pines, Japanese and hybrid larches, *Abies nobilis*, *Cupressus macrocarpa*, sycamore and beech were introduced. All the planting was on single-furrow ploughing carried out with a Cuthbertson draining plough. Planting enjoyed a very kindly season, and at the end of the first year, losses amounted to less than 3% over all.

In Strathy, Sutherland, ten miles west of Skiall on an area of typical North West Highland blanket bog with *Scirpus caespitosus* dominant, pilot plantations of the same type were also laid down. Exposure at Strathy, which lies six miles inland, is, however, much less severe than at Skiall, which is only two miles from the north coast. The main species at Strathy was a coastal variety of *Pinus contorta*, but in little groups among it the following species were introduced: an inland form of *Pinus contorta*, Scots pine, Japanese and hybrid larches, Sitka and Serbian spruces and *Tsuga heterophylla*.

As at Skiall, weather conditions were remarkably favourable during the whole of the first year, and results have been equally good. The plans for both Skiall and Strathy require pilot plantations of the same type to be laid down in three consecutive years, and the present year's repetitions have had a much less favourable start, mainly because of delay and subsequent failure on the

part of the contractors to produce the ploughing equipment. Eventually ploughing was taken over by the North Scotland Conservancy, but even after that was completed, planting was badly delayed by snow, wild weather and transport breakdowns.

DERELICT WOODLAND INVESTIGATIONS

By R. F. WOOD, *Silviculturist, South*, A. D. S. MILLER, *Assistant Silviculturist*, and G. D. HOLMES, *Assistant Silviculturist*

The recently completed Census of Woodlands has clearly shown the scale of the problem which confronts us in the rehabilitation of the degraded broad-leaved woodlands of Britain. Research into conversion of the principal types has been given priority, and the work proceeding falls under four main heads.

(I) The layout and management of demonstration areas located on the commonest types, to show in operation the best-known methods of conversion.

(II) Experimental work on various methods of converting coppice, scrub, etc., including the study of existing experiments and the laying down of new ones where fresh evidence is required.

(III) Particular studies on the control of the more important woody weeds, including the use of "arboricides".

(IV) Investigation of particular areas where conversion operations already carried out have thrown light on problems of general importance.

Some notes on work proceeding under the first three heads are given below. Under (IV) an investigation of the very interesting Gardiner Forest in Wiltshire has not yet reached the stage for report.

I. Demonstration Areas—Alton

About 100 acres of Alton Forest in Hampshire have been handed over to the Research Branch, some fifty acres of which will be managed as a demonstration area, the remaining fifty being used for experimental purposes. This is a chalk site, and a similar demonstration is also planned for a heavy clay type.

Prior to handing over to the Research Branch, the Conservator, South-East England, fenced the area and brought the squirrel and rabbit populations down to very low levels.

Work on the derelict area at Alton, which has occupied a good deal of the time of the Derelict Woodlands research team to date, can be considered in six clearly defined stages.

(1) A survey was made of the existing stock. There are about 2,500 scattered standard trees which form the remnants of a previous forest crop, mostly beech, oak, and ash of such poor timber form and condition that the exploiting timber merchants chose to leave them. During the last twenty-five years the greater part of the area has become covered by dense natural regeneration consisting mostly of sycamore and ash, much of which has been very seriously damaged by grey squirrels and rabbits.

Because both the type of advance growth, and the extent of damage, varied every few yards, it was necessary to draw a stock map to a very large scale in order to obtain an accurate assessment of the state of the young crop, and

when this survey was plotted at one inch to forty feet, it showed that over a third of the area carried advance growth which was too badly damaged to be acceptable, scattered mostly in very small groups over the whole forest.

(2) A soil survey was also made and, the trends being more general, was plotted to a scale of 1/2,500; this showed that over two-thirds of the area a deep brown-earth soil of Tertiary origin overlies the chalk, but in the remaining third the soil becomes progressively more shallow until it produces a few acres of a very thin rendzina.

(3) A detailed examination of individual trees was necessary to see which species were suited to the site.

About a hundred young trees of ash, sycamore and birch, with ages from fifteen to twenty-five years, were cut, and their rates of growth examined to see whether there was any falling off of increment at this stage. It was found that in all cases vigour was being maintained.

A series of Pressler increment borings was made on the standards, and a number of old stumps were examined to discover which species kept up a good growth rate until they were mature.

These observations suggested that sycamore and ash might confidently be expected to reach small timber size at a reasonable rate of growth and that beech would almost certainly retain its vigour until very large; though good oak could be grown on the better soils, the volume production would be much less than for beech.

(4) It was a matter of considerable importance to know from what degree of damage by rabbits and grey squirrels the young trees could recover, so as to have a good prospect of producing saleable material.

A number of sample trees of ash and sycamore showing typical damage were felled, and it was discovered that the annual increment in height and girth were affected to a surprisingly small degree; each tree was then cut lengthwise so as to expose the whole pith and show to what extent heart-rot or other fungal invasion had followed the initial damage. This showed that with ash a rot or "black heart" always followed damage; but that with sycamore the tree may be accepted with some confidence, where:—

(*a*) The tree appears vigorous and to be healing the wound,

(*b*) The damage is close to the ground and initially did not cover more than half the circumference of the stem,

(*c*) Any wood still not healed over is hard and appears sound.

(5) The standards were examined and each was classified according to the following categories:—

(*a*) Young healthy trees of good vigour and form which will appreciate in value, and which are to be kept as part of the new crop.

(*b*) Trees which, for reasons of form or soundness, are not to be retained.

These are sub-divided into:—

(i) Trees which it will pay to fell when all incidental expenditure is taken into account.

(ii) Those which it would not pay to fell; such trees to be killed standing.

It was found that on the whole area of 100 acres there were only about 100 young trees good enough to be allowed to grow on, and conveniently these occurred in small groups.

(6) Prescribing for future management and writing the Working Plan.

After arranging for all the saleable standards to be cut and extracted, very nearly the whole of the area could be covered by the following four prescriptions:

(*a*) Groups of older hardwoods almost forming a canopy, including standards which are to remain, and patches of tall birch; to be underplanted with beech.

(*b*) Groups of undamaged or lightly damaged advance growth: to be accepted, thinned, and where necessary, pruned to improve stem form.

(*c*) Badly damaged groups of regeneration: to be cut right back and the resulting coppice shoots singled at a later date, and tended so as to produce a crop.

(*d*) Bare areas either existing or created by felling the standards; to be planted with beech.

Much importance is attached to the precise assessment and recording of the work at all stages, so as to provide a fully documented demonstration.

II. Existing Experiments

The conversion of worn-out coppice to beech high forest has been studied at Collingbourne Forest, Wiltshire, since 1943. The area concerned is fairly typical of much derelict woodland on chalk, the original oak overwood having been removed, leaving patchy mixed coppice varying from dense tall hazel to practically open conditions with sporadic birch. The coppice is usually mixed, ash, oak, field maple and birch occurring in addition to the hazel.

The experiments laid down in 1943 had as their principal objective the demonstration of silviculturally and economically sound methods of re-afforesting such worn-out coppice. Partial clearing in strips or groups was done which, in addition to reducing the initial work, maintained side shelter for the planted trees. In the taller coppice, groups six feet × six feet at twenty-one foot centres were cut out, and in the shorter coppice strips twenty-one feet wide were cleared, alternating with uncleared coppice belts also twenty-one feet wide.

These experiments do not provide direct comparisons between strip and group methods of replanting. They do however afford demonstrations of the two methods under slightly different conditions, and in addition they include an investigation into the best number of plants per group, and also compare the behaviour of ash, sycamore and oak, with beech, which is likely to prove the principal species used in the re-afforestation of such types.

From the Collingbourne work there have been obtained, so far, a number of indications, which may be summarised as follows:—

(1) Beech, as might be expected, is the easiest species of those tried to establish on this type.

(2) The small six feet × six feet cleared groups, spaced at 100 to the acre, while economical as regards the original preparation and planting, are most expensive to maintain, requiring frequent attention to prevent suppression of the beech, and presenting difficulty in getting rid of the slash.

(3) The strips are relatively much cheaper to maintain.

(4) On this particular site, there are no suggestions of benefit from the increased side shelter in the groups as compared with the strips. Indeed (though this treatment was not included in the experiments), complete clearance has given quite satisfactory results on neighbouring areas.

It should be said that Collingbourne may be exceptional as regards this apparent absence of shelter benefit. Large differences in the growth of beech, apparently related to the height and type of sheltering coppice, are noticeable at Gardiner Forest (a very similar type), and here a detailed investigation is being carried out to determine if possible what are the important factors influencing the growth of beech in a coppice environment.

One of the uncertainties encountered at Collingbourne, which is of general importance, is the degree of weeding or cleaning necessary in group or strip methods in order to achieve a satisfactory crop by the cheapest means. Accordingly, the weeding treatments in Expts. 4 (Groups) and 1 (Strips) have been diversified. The groups are now subjected to three weeding regimes: A. no further weeding or cleaning: B. weeding and cleaning only sufficient to give clear top space to the tallest tree in the group: and C. weeding and cleaning to allow all trees in the group clear top space. It is of interest that in applying these treatments for the first time, treatment B. (favouring one plant only) took on an average only half the man/hours spent on treatment C. (where the whole group is favoured). In such groups this is of importance as it is only contemplated that there will be one final tree in each group; and though the most vigorous may not be the most desirable tree, it appears that a large saving may be possible by accepting it at a suitably early date, and some part of the saving might well be spent on improving its form by attending to double leaders, etc.

In the strips, we wish to know whether we shall obtain a commensurately better crop by continuing to weed and clean (mostly along the encroaching margin of the coppice belt) so that all planted trees are available for choice of the final crop, than by ceasing to weed and clean when it is clear that the centre rows of the planted strip are safe from the coppice belts, (a stage which has already been reached in the strips in Expt. 1).

Such highly contrasted experimental weeding and cleaning treatments may never be exactly followed in practice, but they should draw attention to the big potential differences in expenditure between more and less intensive methods, and their effects on the resulting crops.

III. Chemical Control of Woody Weed Growth

During 1949 this subject was investigated chiefly from the point of view of working out techniques for killing or controlling woody weed species. Control by hand methods, especially of coppicing species, can prove troublesome and expensive during the establishment period of a new crop, due to the frequency with which weeding must be done.

By the use of chemicals it is hoped to avoid the expenses of repeated cuts, by an early and complete kill of the stump and root system.

Work was concentrated on rhododendron (*Rhododendron ponticum*), hazel (*Corylus avellana*), blackthorn (*Prunus spinosa*) and ash (*Fraxinus excelsior*), during 1949. The preliminary experiments have been trials of various concentrations of likely compounds, applied in spray form to several growth stages.

The growth substances di-chloro-phenoxy-acetic acid (D.C.P.A. or 2,4-D), and tri-chloro-phenoxy-acetic acid (T.C.P.A.) were tested on all species in aqueous solution, or in oil. Other compounds tried include ammonium sulphamate, sodium chlorate and sodium arsenite. In all species applications were made (1) to freshly cut surface of stump after felling of growth, or (2) regrowth on stumps cut one year previously.

RHODODENDRON

Rhododendron treated in August, 1949, shows clear-cut responses in the regrowth stage. Growth substances produced the earliest signs of damage

as shoot malformations. None of these compounds were lethal, even though very heavy application rates were tested, e.g., 18 lb. per acre for 2,4-D. The growth substances proved more effective when applied as esters in odourless kerosene, probably due to increased leaf penetration, but no kills have been recorded.

Ammonium sulphamate at 250 lb. per acre and sodium arsenite at 50 lb. per acre, both at 200 gallons aqueous solution per acre, gave complete kill of vigorous shoots. Application to freshly-cut surfaces shows a similar effect, but final conclusions cannot be made until the end of the 1950 season. There is an indication that D.C.P.A. and T.C.P.A. have a greater effect when applied to cut surfaces.

HAZEL

Tests on hazel at similar growth stages show a similar result. Ammonium sulphamate has proved most effective as a mid-summer application at 250 lb. in 100 gallon per acre. Several D.C.P.A. and T.C.P.A. treatments gave complete kill of young regrowth, but no serious damage was done to the stool. Treatment with a mixture of the butyl esters of di-chloro- and tri-chloro-phenoxy-acetic acids killed the shoots particularly well, and weakened the stools appreciably. Experiments are being continued to investigate the effect of varying the season of application of these compounds, and also of repeated applications in one season.

ASH

Quite large stumps of ash can be killed by use of ammonium sulphamate, applied as crystals, to notches in the recently cut stump surface, at the rate of about half an ounce of crystals per stool. Stump spraying with up to 40 per cent. solutions has given good results. A point which was shown rather clearly in these experiments, was the almost complete absence of lateral translocation of these poisons. Sulphamate applied to an axe cut in the bark of a stool kills above and below the cut, but with very little spread of the effect sideways from the cut.

FOREST GENETICS

By J. D. MATTHEWS
Geneticist

General Programme of Improvement

Three principal methods are being used to improve the inherent quality of future plantations in Britain. They represent three stages in the progress towards the ideal of full control over parentage.

1. MASS SELECTION

The best stands in the country are being listed by means of the 1947 Census of Woodlands. The older woodlands with well documented histories are regarded as relatively safe seed sources, after the obviously bad trees have been removed. The younger woodlands of unknown origin will be tested by observations on the plantations formed with their progeny. By this method the parent trees are only known in the mass.

2. MOTHER TREE SELECTION

Vigorous and well-formed mother trees have been selected in the best of our older woodlands and plantations, and seed will be gathered from them during several consecutive years. The progeny will then be compared against a standard race, and "seed plantations" will be formed from the offspring of the best parents. The mother trees are now known individually whilst the fathers are unknown.

3. SELECTION OF BOTH PARENTS

A series of outstanding phenotypes will be tested by vegetative propagation and controlled pollination. The trees with outstanding genotypic constitutions will be included in a series of "seed orchards" established and treated for regular seed production in a similar manner to fruit orchards. Both male and female parents are now of known value. It is at this stage that inter- and intra-specific hybrids will be developed.

Progress during the year is described by species which are arranged in their order of importance. Measures to bring about faster rate of growth, higher quality of timber, resistance to disease and insect attack and improved silvicultural qualities, have been initiated in five species, namely, Corsican pine, beech, European larch, Scots pine, and Sitka spruce.

The rate at which the growing stock of British woodlands can be improved depends almost entirely on the quantity of seed of good inherent quality which can be made available. Full advantage must be taken of good seed years. Methods of forcing fruit production are also required, and considerable attention is being paid to seed orchard techniques.

Corsican Pine

STUDY OF VARIATION

The principal characteristic looked for in Corsican pine is vigorous growth. The standard set for stem form is high, and the main axis of seed parents must be persistent and without any tendency to forking. The principal limiting factor in the use of the timber appears to be the frequency and size of knots. Seed parents must therefore show light, regular and flattened branching. Intermediate crown width appears to be most desirable from the silvicultural angle. Capacity to bear seed is also required.

Analysis of the literature and field observations have shown that *Pinus laricio* Poir. (syn. *P. nigra* var. *calabrica* Schneid.) is the most suitable of the varieties of *P. nigra* for use in this country. It has become apparent that while the young stands are often very mixed, they do contain a good proportion of the most desirable variety. A number of seed stands have been selected on each of the four main site types, i.e., the coastal sand dunes of Scotland and Wales; the Bunter sandstones of the Midlands; the Breckland soils of East Anglia, and the Bagshot sands of South-East England. Twenty-one single trees have also been marked for testing and subsequent inclusion in an experimental seed orchard.

Considerable attention has been paid to the fruiting of Corsican pine in this country. Some seed is available in most years from Corsica, but home supplies are not nearly sufficient to meet the present demand. It is considered that there are three main reasons for this shortage:—

(1) Age or degree of sexual maturity:—The bulk of plantations are under twenty-five years of age (this being the age when the species normally commences coning in Great Britain).

(2) Silvicultural treatment:—The stocking at which the plantations are normally kept is above the optimum for the heavy crown development

essential for regular cone production. At present only dominant and ride-side trees receive sufficient light or possess adequate crown development for fruiting. Twenty-five year old trees within typical plantations are rarely bearing more than ten cones per tree, while an isolated tree in the Bedgebury Pinetum (Kent) with a full crown yielded two and three quarter ounces of seed from 350 cones. Similarly at Thetford Forest (Norfolk), trees underplanted with beech and at a wider spacing were bearing quite heavily when compared with neighbouring trees in pure plantations.

(3) Site conditions:—Because of its adaptability the species has been used on somewhat difficult sites with a low nutrient status. While this may tend to advance the first onset of fruiting, nutrient factors generally will probably be working against regular heavy flowering and cone production.

An appraisal of the current cone crop has been made during the year and it appears possible that as the plantations grow older there will be sufficient seed available in a good year to meet demands. Meanwhile efforts are being made to correlate external morphological characteristics with inherent quality, and an intensive nursery trial has been laid down this spring at Alice Holt. This compares the progeny of six imported and four home-collected seed lots with that of fifteen of the selected individuals taken from Alice Holt Forest and the New Forest (Hants), Rendlesham Forest and Holkham Estate (Norfolk) and Bedgebury Pinetum (Kent).

PROPAGATION

During the spring some 400 grafts of Corsican pine were made, half in the open nursery and half under glass. To date, it appears that between thirty and forty per cent. of these grafts have taken, and the establishment of an experimental seed orchard is a possibility during the coming spring. It became clear that root stocks must be left in the ground one complete year before grafting to allow them to become fully established. Only moderate success has been obtained with root stocks that were transplanted this year. Greater success was also obtained with freshly collected, slightly active scion material, as against that obtained with stored, dormant material. Approximately twenty grafts were made of each of the selected trees. These will constitute a trial of vigour and also provide material for a study of morphological differences. Other grafts were on different root stocks with the object of discovering which pine species will provide a "dwarfing" effect between root stock and scion which will bring about early fruiting.

In the search for a dwarfing root stock two lines are being followed:—

(1) The use of precociously and repeatedly flowering trees as root stocks. In most plantations individuals are found which flower repeatedly from a very early age and also show poor vegetative growth. It appears, from twenty years experience with fruit orchards, that this dwarfing effect provides the best means of obtaining persistent and early fruiting of the scion.

(2) The use of root stocks of different species which are more slowly grown and normally flower early in their life cycle. The species tried this year have been Scots pine, the slower growing varieties of *Pinus nigra*, *Pinus contorta* and *Pinus mugo* (*P. montana*). Successful grafts which have been made in pots, will be treated with various combinations of N, P and K to ascertain whether manuring can be used to supplement the root stock effect.

A large experiment with dormant cuttings was laid down in February. The methods which have been successful in America and Australia with *Pinus radiata* were applied to Corsican pine and Scots pine. The treatments consisted of four applications of growth substance, repeated under seven different propagating conditions. At the end of the period under review the *Pinus radiata* had begun to root under the most favourable propagating conditions of closed case, high humidity and bottom heating to 65° or 70°F. The cuttings of Scots pine and Corsican pine, while they have not yet rooted, are extremely healthy in appearance, and may in time begin to develop roots. Juvenile material of Corsican pine has been rooted, and further research into methods of obtaining juvenile propagating material is now under way.

BREEDING

Observations made in the field indicate that there are individuals within the variety *calabrica* which are predominantly male or female. In the selection of the twenty-one trees for testing, stress was laid upon the amount of cones being borne, with the assumption that these trees would again bear under favourable conditions. It is not yet clear whether this sexual difference is linked with any other vegetative characteristic.

Beech

STUDY OF VARIATION

The genetics of beech has been studied for forty years, principally in Denmark, Germany and Switzerland. It has become clear that while environmental factors are of the greatest importance in the development of high quality timber, vigour of growth, straightness and persistence of stem, angle and size of branching, width of crown and time of flushing and flowering are to a large extent genetically determined.

The most profitable market for beech appears to be that offered by the veneer and furniture industries. Selection of parents for seed orchard purposes has accordingly been made from stands containing a high proportion of trees suitable for these purposes. Another factor in selection is that of time of flushing, and several late flushers have been marked for possible future use in chalk downland afforestation. These late flushers are less susceptible to damage by late frosts in early growth.

Seed of over twenty provenances collected by the Ecologist was available for sowing in the spring of 1949, and a small intensive nursery trial was laid down. Observations made during the year yielded the following results:—

(1) A positive correlation between percentage germination in the nursery bed and the percentage of sound seed as recorded in a simple cutting test.

(2) A correlation between percentage germination in the nursery bed and the weight of one thousand seeds. In general, high seed weight gave high germination.

(3) An assessment of height (by inch classes) was made at the end of the growing season. The seedlings were grouped into three size classes, large, medium, and small, and were later lined-out in a replicated extension of the experiment. When the overall distribution of the seedlings was examined, it became evident that the provenances could be grouped into three classes as follows:—

(*a*) Provenances with marked vigour and abnormal production of large seedlings (ten inches to twenty-two inches). In this group were the provenances named Orton House Policies (Moray),

Kingscote Estate and Cirencester Park (Glos.), Savernake Forest (Wilts.), and Brandsby Estate (Yorkshire).

(*b*) Provenance with average vigour and normal production of seedlings in the three height classes. Mabie Woods (Dumfries.), Aldroughty and Westfield near Newton (Moray), Charlton Forest (Sussex), and Forest of Dean (Glos.) came within these limits.

(*c*) Provenances with poor vigour and abnormal production of small seedlings (up to seven inches). This group included Rewell Wood (Sussex), Gordon Castle (Moray), Slindon Forest (Sussex), Benmore (Argyll).

Table 8 gives the details for the class (*a*) provenances and also for representatives of the other two groups. The percentage culls figure includes plants of all height classes which were deformed or forked.

HEIGHT GROWTH OF ONE-YEAR BEECH SEEDLINGS OF VARIOUS PROVENANCES

Table 8

Provenance	Ref. No.	Mean Height inches	Height Classes 0″–7″ %	8″–9″ %	10″–22″ %	% Culls	Vigour and Form of Parent Stand
Orton House .... (Moray)	13	9.88	25.5	25.2	49.3	37.0	Mature, wide crowned, branchy trees. Moderate veneer stand.
Kingscote, Nailsworth (Glos.)	16	9.48	23.6	30.6	45.8	46.0	Mature, vigorous and well formed. Very good veneer stand.
Savernake (Rough barked) (Wilts.)	14	9.33	35.8	17.2	47.0	42.2	Mature, vigorous, rough barked, poor quality.
Cirencester Park (Glos.)	17	9.27	28.0	30.8	41.2	49.2	Mature, vigorous, well formed. Very good veneer stand.
Brandsby Estate (Yorks.)	20	9.24	26.5	32.3	41.2	52.0	Mature, vigorous. Forking prevalent.
Savernake (Typical) (Wilts.).	15	9.02	29.0	30.6	40.4	51.3	Mature, vigorous, coarsely branched. Spiral grain common.
Mabie Woods .... (Dumfries.).	19	8.96	36.4	31.7	31.9	100.0	Mature. Forking prevalent. Heavy branching. Poor stem length and form.
Edge End, Forest of Dean (Glos.)	18	8.78	31.4	30.3	38.3	41.2	Mature, vigorous. Branching coarse. Much fluting and spiral grain. Very poor quality.
Benmore School (Argyll.).	5	7.63	47.8	33.4	18.8	53.6	Mature, mod. vigorous. Forking prevalent. Heavy branching. Moderate quality.

While it must be stressed that this form of mass selection is far from critical it is at least very practical. The results obtained to date show that seed collected from vigorous well-formed and well-tended plantations will yield a high proportion of vigorous one-year seedlings—in this case often fit for planting out on the better forest sites. This experiment will be repeated in subsequent mast years to obtain an indication of the constancy of the results.

PROPAGATION

Six selections were made in the very fine Kingscote stand, and five at Cirencester Park. A few successful grafts have been obtained from these and from the ten other trees from which material was collected.

The Whip graft was used, the root stocks being one-plus-one or one-plus-two transplants. The scions consisted mainly of three-or-four-year wood bearing several dormant buds, the number of normal foliage buds being reduced to one or two per scion. This work was carried out both under glass and in the open nursery.

BREEDING

Flushing observations were continued at Crawley Forest (Hampshire). Pollen from five beech individuals was sent to the Hørsholm Arboretum, Denmark, where a ten year programme of improvement by breeding is in progress.

European Larch

STUDY OF VARIATION

As many of our finest larch stands are sited in North-East Scotland, the first group of selections have been made in that area. Material was obtained from twenty very beautiful old trees and the propagation (by grafting) has been quite successful. Establishment of an experimental seed orchard is now a practical proposition.

Particular attention is being paid to the past history of the selected trees, with the object of isolating a strain with resistance to die-back. In this connection the Scottish provenance trials of larch will be intensively studied during the coming year, and every advantage will be taken of the currently developing larch seed crops.

BREEDING

Larch appears to be a good subject for experiments on the forcing of fruit production by means of different types of root stocks, root pruning and manuring. Accordingly a section of the agricultural type nursery at Alice Holt has been prepared for this work, and representative grafts of the selected parent trees will be included in forthcoming trials. Seedlings from the 130 year old larch stand at Varel in North-West Germany are also to be included in these experiments. This stand is said to be of Scottish origin, and has remained healthy in an area where other origins have suffered severely from die-back.

Scots Pine

STUDY OF VARIATION

Three main groups of Scots pine have been studied during the year, and some very fine mother trees have been selected. The first group consisted of stands which can be traced to the Old Caledonian Forest and the principal place of study has been the Castle Grant Policies (Moray.). The second group has been the pines on various parts of the Bagshot Heath, in Surrey, and fifteen selections have been made on the Crown Commissioners' land at Windsor.

Finally, three individuals have been selected from the interesting East England provenance at Croxton Park (Thetford Forest) Provenance Trial. The intention is to cross these with a similar number of individuals from the Glen Garry and Loch Maree (Scottish) provenances in the same trial.

PROPAGATION

A search for a dwarfing root stock has led to the discovery of a prostrate individual of *Pinus mugo* (*P. montana*). This tree bears crops of cones in almost every year.

Attempts are being made to stimulate the production of juvenile material for propagation by cuttings in a group of four-year-old transplants at Alice Holt. This work is part of the general study of the value of juvenility in the vegetative propagation of pines.

Sitka Spruce

STUDY OF VARIATION

Considerable attention has been paid to the location of late flushing individuals in frosty localities. Reports have been received of several trees with this characteristic, and three speciments found at Croxton Park (Thetford) were dug up and brought to Alice Holt. One of these trees has borne female flowers this year and controlled pollination was carried out. It is hoped that this will give information about the inheritance of this valuable late-flushing characteristic.

Certain trees reported to be resistant to attack by *Neomyzaphis* have been marked down for future propagation and testing.

Thuja plicata

PROPAGATION

Two twenty-nine-year-old trees of good form and vigour were selected in Bagley Wood, Oxford. They have been the subjects of a propagation experiment, and are to form the nucleus of a clonal collection of this species.

One hundred and twenty cuttings from each tree were inserted on 20th March, half with trimmed heels and half untrimmed. The effects of applying indole-butyric acid as a concentrated dip ($\frac{1}{2}$ mg. I.B.A. per c.c. 50% alcohol) or with a talc carrier (6.25 p.p.m. in talc) were also compared.

The propagation conditions consisted of a closed case with electrical bottom heating to 70°F. The medium was coarse Bedford sand (75%) and peat (25%). Assessments were made fifty-eight and seventy-six days after insertion.

Of the three factors examined, the effects of the growth substance were greatest. Indole-butyric acid increased the speed of rooting, the number of cuttings rooted, and the total length of roots per cutting, when compared with the untreated controls. The concentrated dip method of application resulted in masses of small roots being produced on the stem, and this tended to reduce the number of more desirable wound roots per cutting.

The experiment has shown that there is no advantage to be gained by trimming the heel of dormant cuttings of *Thuja plicata* and in fact the bigger callus produced by the untrimmed cuttings may result in more wound roots being developed.

The experiment has been repeated in an unheated barn cloche, the medium being pure sand. The experience gained will also be applied to × *Cupressocyparis leylandii.*

There are seven experiments relating to this last named species in progress at present, the factors studied being types of media, time of taking the cutting, size of cutting and the use of growth substances.

Metasequoia glyptostroboides

PROPAGATION

This recently discovered living relict species from China has shown great vigour and growth when raised from seed in this country. Trees with a height of 115 feet and a diameter of four-and-a-half feet occur in Hupeh Province—the "type" tree being, however, rather heavily branched and spreading.

The possibilities of rooting dormant cuttings of this species were investigated during the winter for two reasons:—

(1) To provide information about the decrease in ease of rooting which apparently accompanies increase in age with most species.

(2) To give a measure of the maximum rate of propagation from a single seedling with a desirable genotype.

Whole branch cuttings ranging from three to six inches in length were inserted on 14th December. They consisted of one-year wood with a small trimmed heel of two-year wood. Twenty-four cuttings were taken from a three-year-old individual and fifty-one from several two-year-old potted plants. The cuttings were inserted at once into a closed propagating case. The rooting medium was the same as that for *Thuja*, and the electrical bottom heating gave a temperature of 65°F., later raised to 75°F. The cuttings flushed, and two months after insertion began to develop roots, the less vigorous being the first to root. Between 14th and 18th March twenty-six cuttings were potted up, followed subsequently by thirty-five others, giving a 71% result. The older plant yielded the more vigorous material, which tended to root more slowly but gave a better type of plant.

Soft wood cuttings of this species (taken in July) have proved easy to root.

Miscellaneous

A short tour of Continental forest tree breeding stations was made during September. The institutes visited included:—

(1) The Poplar Research Station, Grammont, Belgium (Dr. C. Muhle Larsen).

(2) The Forest Research Station, Wageningen, Holland (Dr. H. van Vloten).

(3) The Horticultural Research Station, Boskoop, Holland (Dr. E. F. Jacobi).

(4) The Hørsholm Arboretum, Hørsholm, Denmark (Dr. C. Syrach Larsen)

(5) The Forest Tree Breeding Institute, Ekebo, Sweden (Dr. C. L. Kiellander).

The object of the tour was the study of the general organisation of tree breeding. Very valuable visits have also been made to the East Malling Research Station, Kent, where apple and other fruit orchard practices were studied.

A small exhibit (nine feet by five feet) was prepared for the Agricultural Shows. It has stimulated forty-three inquiries to date.

PROVENANCE STUDIES

By R. F. WOOD, *Silviculturist, South*, and
R. D. PINCHIN, *Assistant Silviculturist*

Beech

Detailed studies on origin of seed in beech were not begun in this country until 1942. At that period it had become apparent that much of the beech planted in the Forest of Dean during the previous twenty to thirty years was of quite exceptionally bad form, and the hypothesis suggested itself that we had in the Dean a very poor strain, possibly selected out over past centuries by continual felling of the best and leaving of the worst.

We have not so much reason to complain of the vigour of our beech, though other things being equal, it is obviously desirable to find which sources of collection will give us the most vigorous stock. The chief fault of form in beech which it is necessary to correct is the prevalence of forking. Other undesirable characteristics, which may or may not be connected, are stem fluting and heavy development of side branches. For certain localities where late spring frosts are a limiting factor, we also wish to find strains of beech which are the least prone to frost damage. The provenance line of approach is to discover which strain or sources of seed collection produce stock which has the highest proportion of individuals with inherited tendency to produce desirable characteristics. Since the form of beech is almost certainly highly influenced by environment, the finer differences between strains may be difficult to distinguish, but we have every expectation that some part, at least, of the large observed variation between stands of beech can be attributed to seed origin.

One experiment planted prior to 1942 gives us some evidence of provenance differences. This is at Crumblands, Tintern Forest, Monmouthshire, where a shelter-belt round a Research block was planted with beech, principally to get information on the best age and type of plant. However, three seed origins were utilised in such a way that some comparison between them is possible. These were a local Dean lot, a lot from the New Forest and one from an Aberdeenshire source. It is fairly obvious that the last of these is considerably the most vigorous, (followed by the New Forest), but none of the origins exhibits desirable form, though minor differences are observable. In particular, the Dean origin exhibits the forking and "twining" (that is, the tendency of two or more leading shoots to twist or twine together) of leaders which is so marked in much of the Dean beech.

Trials were laid down in 1942 at Savernake Forest in Wiltshire and at Abbotswood in the Forest of Dean. Four seed origins are common to these two experiments, namely West Dean, Sussex (where the beech stands are of very desirable form); a Dutch seed lot, and two lots (obtained by different seedsmen) from the Carpathians. The Abbotswood trial also includes the local Dean Forest lots, and a lot of Scottish origin. Both experiments have been assessed as regards height growth and form of the beech; the form being evaluated on the percentage of stems falling into grades of quality, taking into account, firstly, the presence of a single leader, followed by straightness of stem. The Savernake data are probably the most reliable, the site being more uniform and the experiment having four replications against only three at Abbotswood. At Savernake the Dutch origin has narrowly led the West Dean lot in height growth since the time of planting, and appears to be increasing its lead. The Carpathian lots are well behind at each site. At Abbotswood, the West Dean lot is

vigorous, and it has a lead in height growth over the Dutch beech, which is the next tallest, of about 11%. (The height of the West Dean lot here is the mean of a single plot and must be regarded with caution.) At neither site has the form of the beech had time to show itself fully; however, at Abbotswood there are appreciable differences. The West Dean origin has at this site, 58% of the stems free from forking, against 41% in the next best lot; this is probably a more reliable comparison than that based on vigour. The Forest of Dean (Nagshead) lot is much the poorest; it is not vigorous and is coarse and much forked. The Forest of Dean (Mailscot) lot is vigorous but of only moderate form. The Tintern lot has a good proportion of unforked stems but is the least vigorous origin present. At Savernake, form is not well differentiated; this is probably due to the frosty nature of the site; but though differences are slight, the Dutch lot appears best, followed by the West Dean one.

These two trials will no doubt give a much clearer picture in a few years time; we can only say at present that measurable differences appear to be developing with some consistency. It is encouraging that a lot selected from a desirable stand (West Dean) has stood up well against "stock" lots not so selected.

More recent experiments at Savernake have widened the number of seed sources under investigation, to include Cotswold stands of merit, and Irish and French sources. Advantage was taken of the excellent mast season of 1948/9 to collect a very wide range of home beech lots, which were sown in the spring of 1949 and are under intensive study in the nursery prior to being planted out in the forest as a provenance trial. (See previous section on Forest Genetics, page 40.)

Scots Pine

In last year's report there was a note on the measurements of height growth and form made in the provenance trial at Croxton, Thetford Forest, (Expt. 18, P.32). Briefly, these measurements showed that the most vigorous height growth was found in the strains originating between the latitudes 48°N. and 52°N., but that better form (straighter stem and lighter, less spreading branches) was found in the origins from higher latitudes, for example in the Scandinavian and Scottish "races". One seed origin, the local East England collection, to a large extent combined the properties of vigour and good form. See Table 9 overleaf.

Since then, the experiment has been thinned for the first time, and different measurements of the yield are available. These figures, as can be expected, confirm the previous evidence based on height growth, but also emphasise the race differences present. The following short table includes examples from the chief zones represented, and serves to show what scale of differences in yield may be expected from seed origin at this site. The question of form, which in the last instance turns on value per cubic foot of produce, cannot readily be answered. However, it is clear that since the early yield differences may be so great, it is highly desirable to find good form in a vigorous strain. A most desirable form may be coupled with yield capability so low that the crop value may not compare with a much coarser, high yielding type. Again, it is not safe to assume that strains which appear vigorous at an early stage will always continue in the lead.

Eighteen-year-old Corsican pine sample plots in the Thetford region, of similar stocking, may have "Total Crop" volumes in the order of 1,200 cubic feet per acre (over bark) and mean annual increments of 67 cubic feet per acre.

Corsican Pine

We have been unfortunate in our race studies on Corsican pine (or more strictly, varietal studies of *Pinus nigra*). An unreplicated set planted at

GROWTH RECORDS OF SCOTS PINE OF VARIOUS PROVENANCES AT CROXTON, THETFORD FOREST, NORFOLK

Table 9 (Expt. 18, P.32)

Origin	Latitude (North)	Age in years	No. of Plots	Mean height of 100 tallest trees per acre feet	Total crop (standing volume plus thinnings cubic feet per acre (over bark)	Mean annual increment cubic feet per acre (over bark)	Remarks
Valkjarvi (Finland)	62°	17	3	20.0	218	12.8	
Flak (Norway)	58°	17	3	21.0	327	19.2	
Riga (Latvia)	57°	17	3	22.5	381	22.4	
Glen Moriston .... (Scotland)	57°	18	3	21.0	263	14.6	Lowest Scottish
Cawdor (Scotland)	57°	18	3	25.0	548	30.5	Highest Scottish
Allenstein (East Prussia).	54°	17	3	24.0	518	30.5	
East England	52°	18	3	28.0	674	37.5	
Kassel (Germany)	51°	17	3	26.0	671	39.5	
Wangenbourg .... (France).	49°	17	3	26.0	607	35.7	
Sopron (Hungary)	48°	18	3	26.0	734	40.7	
Trentino (Italy)	46°	18	3	23.0	389	21.6	Not strictly comparable due to poorer stocking, but it is clear that this origin is unhappy at this site.

Bedgebury Forest between 1932 and 1934 was largely destroyed by fire in 1943, and the remaining English trial, at Wareham, was burned in July, 1949.

However, there has been no evidence to suggest that the Commissioner's policy in favouring the true Corsican type has been incorrect.

Pinus nigra is distributed through Southern Europe and Asia Minor, being found as fairly distinct forms in a number of quite separate localities. The forms represented in Wareham Expt. 14, planted in 1932, were the following: (1) and (2) *P. laricio* Poir. (*P. nigra* var. *calabrica* Schneid)—two lots from Corsica itself; (3) and (4) *Pinus nigra* var. *caramanica* Rehder from Turkey, and Mt. Aetna, Sicily respectively; (5) *Pinus nigra* var. *cebennensis* Rehder from the French Cevennes; and *P. laricio* Poir. (*P. nigra* var. *calabrica* Schneid.) from the Calabrian region of Italy. The following table gives the measurements made in 1948, the year before the experiment was destroyed.

The Austrian pine, the characteristics of which are well known, was not included in this trial.

Although this is a most infertile site and all growth was very poor, the superiority of the true Corsican as regards vigour and form is clear enough, and very similar indications were obtained at Bedgebury Forest in Kent. One principal habitat of *P. nigra* does not seem to have received attention in these trials, that being the Iberian Peninsula. The Spanish black pine is usually grouped with var. *cebennensis*, and though there is no particular reason to suppose that it will be superior to the Corsican pine, it seems at least worth a trial

GROWTH RECORDS OF VARIOUS PROVENANCES OF CORSICAN PINE AT WAREHAM FOREST, DORSET

Table 10 (Expt. 14, P.32)

Origin	Mean height in feet	Mean shoot in inches	Remarks on Form
(1) Corsica	7.1	8.5	Slightly heavier branching than (2)
(2) Corsica (Mr. Blake's collection)....	8.0	9.8	Good stem form, light branching
(3) Turkey	3.4	3.1	Bushy with coarse heavy branches
(4) Sicily—Mt. Aetna	4.8	4.4	Similar to (3) though more vigorous
(5) France—Cevennes	5.1	6.1	Heavily branched with frequent basal bends in the stem
(6) Italy—Calabria	6.2	5.1	Bushy and with sharply tapering stems

in this country. Recently seed has been received from the Forest of Cuenca, and it is hoped to plant out the stock raised from it in comparison with Corsican pine next season. Probably the most we can hope for in these investigations is a variety of *P. nigra* of form comparable to Corsican pine which will extend the range to colder and wetter sites, but the geographical distribution of black pine does not really offer us much encouragement.

Maritime Pine

Maritime pine grows with considerable vigour and attains useful dimensions on the Tertiary sands of the South of England. It has an extremely vigorous tap root development which is capable of breaking a distinct pan, and it is easy to establish by direct sowing. However, trees raised from many of the early sowings have turned out very poorly, the trees being coarse and rough and showing very marked "sweep" at the base of the stem. To some degree this poor form is probably due to overstocking in the original sown patches, but there is also the possibility that race enters into it.

In the middle twenties, sowings of maritime pine were carried out on quite a large scale (at Wareham, Dorset, and Bramshill Forest, Berkshire, amongst others). The chief source of seed was the Landes region of France, 1,770 lb. being imported from this region alone during the years 1924 to 1926. Smaller quantities of seed were also imported from Portugal and from Corsica. Home collections have not been large, but maritime pine has in fact spread quite considerably by natural seeding on certain of the heaths north of Bournemouth, and as it is said to have been in cultivation since 1596, there is the possibility that the home strain may now be distinguished from the more recent reintroductions. The South Africans have favoured the Portuguese race in their afforestation.

A trial field sowing was made in 1949 at Wareham to compare—

(A) Seed from the home strain,

(B) The Landes race, and

(C) The Portuguese race, seed being received from the Forest of Leira.

Owing to an unexpected site irregularity, the height growth of seedlings in the first season was disappointingly uneven, and it was not possible to confirm statistically by actual measurement what had previously been observed with nursery sowings, namely that the Portuguese "race" produced the most vigorous one-year seedlings. Observations of the more successful plots, however, left no doubt that this was so.

Plantings of one year seedlings in the forest showed that the bigger Portuguese seedlings were more difficult to establish than those of local and Landes origins. However, in height growth during the first season they very clearly exceeded the two latter, which were not distinguishable in performance at this stage. The Portuguese seedlings are readily recognisable by their very red shoots, and longer needles. It is not common to see such striking provenance differences appearing so early, and it is to be hoped that the Portuguese race will add good form to its score in due course. Maritime pine has, perhaps, been neglected, and with improved stem form it might find some place on our poorer southern sands.

The International European Larch Provenance Experiments (Planted 1946)

In 1944 the International Union of Forest Research Organisations distributed to certain of its members a comprehensive range of larch seed from various geographical regions of Europe for the purpose of establishing provenance experiments under the control and supervision of the participating organisations.

The collection of thirty-nine seed lots received by the Forestry Commission includes origins from the main regions of the natural distribution of the species. There are thirteen lots from the Austrian Alps, collected at various elevations between 1,800 and 6,000 feet; three from the Italian Alps and two from the Swiss Alps, mostly at elevations between 1,300 and 4,000 feet; two from Slovakia and four from the Sudeten district of Moravia at elevations between 1,000 and 3,200 feet. Seven origins are also included from the coastal plain of north-east Germany, where, though outside its natural habitat, larch has become one of the commonly planted forest species. In addition to the above there is one lot each of Scottish larch from Scotland and Sweden, Japanese larch from Denmark, and Siberian larch from Finland.

It was decided also to include in the experiment five home lots of European larch, from South Wales, North-West England and North-East England. Two of these, North-East England (43/13E), and North-West England (43/13G) were put in at all five centres.

The seed lots of Waldstein (Austrian Alps) and Aldroughty (Scotland), of which large seed supplies were available, will be used as a basis of comparison with the others. Unfortunately, only small quantities of seed of some lots were available, thus limiting the degree of replication which could be adopted.

The planting of this experiment was carried out in 1946 in England and Wales at the five forests of Savernake in Wiltshire, Haugh and Mortimer in Herefordshire, Wyre in Worcestershire, and Walcot in Shropshire. The plants were put in as one-year-one transplants, with the exception of five of the home lots which were one-year-two. Nineteen seed lots were also planted at Drummond Hill Forest in Perthshire in the following year as one-year-one-year-one transplants.

The sites selected for the experiment were felled woodlands, at fairly low elevations, and as nearly as possible uniform as regards soil, climate and general topography. It will therefore be possible to regard each area as one unit of a randomised block layout for the purpose of statistical analysis of assessment data.

Now in its fifth growing season, the experiment has developed in a normal manner with the exception that at Savernake Forest heavy losses were caused by late spring frosts and by drought immediately after planting, and at Wyre Forest considerable injury and losses have been caused by deer and rabbits. Insect damage has also been recorded but not to any serious extent.

Assessments

An annual assessment of total height growth and shoot growth and percentage losses has been carried out up to the present time. Also, in 1948, mid-diameter measurements were begun in order to calculate the slenderness factor (height : diameter). Phenological studies at the flushing and leaf-fall periods have also been made since the spring of 1948.

Quantitive assessment of differential damage caused by insect and fungus attack will be made as soon as the incidence reaches assessable proportions in any particular case.

It is also intended to make assessment, or record the occurrence, of climatic injury such as basal bow, wind-throw, frost damage and snow-break. Physiological aberrations from the normal will also be watched for, as required by the provisions laid down by the originators of the experiment, in particular the occurrence of "basket" growth and "chandelier" forms which in Britain are usually associated with frost and wind damage. Observation of "Lammas" growth will also be made.

Losses at Planting

At Savernake Forest, where all seed lots in the collection are represented, losses were heavy in the first year, necessitating beating up as far as the plant supply would allow with the appropriate race of larch, and with beech, when larch was unavailable. Of the eight lots of European larch which suffered losses of over fifty per cent., four (A.3, A.7, A.10, A.13) came from the Austrian Alps and one each from the Swiss (D.27) and Italian (C.23) Alps, North-East England (43/13E) and Bohemia (I.46), the two latter being heaviest at 76 per cent. As none of these "races" suffered high losses at any of the other centres, it is considered that the heavier losses at Savernake were due to fortuitous local circumstances, and do not signify any particular susceptibility.

Siberian larch, which has since failed almost completely, lost 89 per cent. at Savernake, 85 per cent. at Mortimer and 14 per cent. at Walcot, the only centres where it was tried.

Height Growth

As could be expected, the home lots, being one year older at one-year-two than the Continental lots, figured prominently at the first height assessment at the end of the first season. At Savernake the five tallest were all home lots followed by three Bohemian lots and the standard race Waldstein. At the other four centres, the home lots, North-East England (43/13E) and Aldroughty (43/502) ended the first season some four to ten inches taller than the best of the Continental lots of European larch.

The best criterion at present available of the growth rates of the various races is, however, the assessment made at the end of the third season. Table 11 overleaf shows the best races as regards growth, giving the relative order and mean height in each forest in which they were planted.

The outstanding feature of the height growth data is that the disadvantage of the home lots by virtue of their larger size and more unbalanced development of root and top at planting would now seem to be having its effect. At all five centres, it is observed that the best of the continental lots have overcome the initial discrepancy in height and now surpass the home lots.

The most promising races to date in the collection appear to be the two Bohemian lots (I.45 and I.49), the Harbke race (F.29) from the German Lowlands, near Helmstedt, and the Proskau race (F.32) from Upper Silesia.

Several of the races have shown a comparatively slow rate of growth at more than one centre, the chief among these being those detailed in Table 12 overleaf.

GROWTH RECORDS OF VARIOUS PROVENANCES OF EUROPEAN LARCH AT DIFFERENT FORESTS AFTER THREE SEASONS GROWTH

Table 11 (Planted in Forest Year 1946)

Mark	Origin	Elevation of origin (feet)	Relative Order at each Forest, with Height in Inches
I.45	Bohemia, Hrottowitz	1,350	Savernake 1st. 63.6; Walcot 3rd. 58.1
I.49	Bohemia, Parkowitz	1,150–1,310	Savernake 2nd. 62.9; Walcot 4th. 57.2
F.29	German Lowlands, Harbke	—	Savernake 6th. 60.9; Walcot 1st. 60.6; Haugh 6th. 56.8; Wyre 1st. 52.7; Mortimer 4th. 52.7
E.28	Japanese larch ex Denmark	—	Savernake 8th. 57.7; Walcot 2nd. 59.6; Haugh 2nd. 62.1; Wyre 7th. 48.0; Mortimer 2nd. 53.3
F.32	German Lowlands, Proskau, Upper Silesia.	—	Savernake 5th. 61.0; Walcot 12th. 54.0 Haugh 1st. 70.4; Mortimer 1st. 55.7
K.52	Slovakia, Murau, Liptovsky-Hradek.	3,150–3,430	Savernake 7th. 58.8; Walcot 9th. 55.7; Wyre 6th. 48.5
43/13G	England, North-West	—	Savernake — ; Walcot — ; Haugh 5th. 56.9; Wyre 2nd. 51.4; Mortimer 8th. 50.0
43/502....	Scotland, Aldroughty	160	Savernake 4th. 61.2; Walcot — ; Haugh 7th. 56.6; Wyre 12th. 44.3; Mortimer 12th. 47.5
43/13E....	North East England	—	Savernake — ; Walcot 10th. 54.6; Haugh 9th. 56.3; Wyre 3rd. 54.6; Mortimer 10th. 49.0
A.14	Austrian Alps, Waldstein	1,640–1,970	Savernake 11th. 56.1; Walcot — ; Haugh 4th. 59.3; Wyre 5th. 50.1; Mortimer 9th. 49.7

In general, races of Alpine origin do not occur very frequently in the upper height classes.

The Aldroughty race has behaved rather variably, being fast-growing at some centres and slow at others, as will be seen from the above data. The other race of Scottish larch from Sweden (K.54) has made a slow start at all centres.

The quality of the site for the growth of larch is reflected in the height growth data of the replicated seed lots. At Haugh Forest the rate of growth

EUROPEAN LARCH: SLOW-GROWING PROVENANCES

Table 12

Mark	Origin	Elevation of origin, in feet	Remarks
D.26	Swiss Alps, Lotschenthal	4,920	In the last five at two out of two centres
D.27	Swiss Alps, Graubunden	1,410–2,130	In the last two at three out of five centres
C.25	Italian Alps, Val Vanosta	—	In the last nine at three out of three centres
A.8	Austrian Alps, Murau Murthal	2,950–3,280	In the last four at three out of four centres
43/502....	Scotland, Aldroughty	160	In the last six at three out of five centres
K.54	Scottish larch from Sweden	—	In the last five at two out of three centres

is highest, followed closely by Savernake Forest. There is little difference between the general growth rates at Walcot, Mortimer and Wyre Forests, which show a mean height of several inches less.

A fuller report and detailed analysis of assessment data will be made next year.

SPACING OF OAK IN PLANTATIONS

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

This subject attracted a good deal of attention in the early years of forest research in Britain; in all, seventeen experiments dealing (at least in part) with the spacing of oak in plantations were laid down in the years 1927 and 1928. The experiments were established at the following forests: Dean, Gloucestershire (8), Dymock, Herefordshire (3), Micheldever, Hants. (3), and Alice Holt, Hants. (3).

At that time it was assumed that relatively close spacing for oak was essential, and no spacings wider than 4 ft. × 4 ft. were inquired into (except in the case of bunch planting, i.e., 3 or 6 plants a few inches apart at each position, and even then planting centres were never wider than 5 ft. × 4½ ft.

The closest single plant spacing used was 4 ft. × 1 ft., giving 10,890 plants per acre, but the heaviest stocking (14,520 plants per acre) resulted from bunch plantings of 6 at centres 4 ft. × 4½ ft. In all, 14 different spacings were tried, viz.: 4 × 1, 4½ × 1, 3 × 2, 4 × 1½, 3 × 2¼, 4 × 2, 4 × 2¼, 5 × 2, 4½ × 2¼, 4 × 3 and 4 × 4, all for single plants, and bunch plantings at 4 × 4½, 4 × 5 and 4½ × 5 (all spacings in feet).

Assessment of the Experiments

Spacing experiments have an economic as well as a qualitative side, and we lack information on the cost of planting and weeding incurred in establishing the various plots. As we have, unfortunately, no data on closure of canopy, we cannot estimate whether the wider spacings (which it can be assumed were cheaper to plant) cost more to weed till safe from competition.

It has been necessary to assess the crops as they are today, and to assume that all have received normal tending, and present a reasonably fair picture of the different spacings as they would appear in practice.

Crops have been periodically measured to obtain mean height, and latterly, breast-height girth. Height measurements after canopy formation have been confined to dominants and co-dominants, and correspond to the effective or top height of the crop. In the last two seasons an attempt has been made to assess the quality of the crops, the stocking and distribution of dominants and co-dominants falling in various form classes being recorded.

General State of the Crops

The experiments are all in canopy and approaching the stage for first thinning. Height growth varies considerably between sites, mean annual height increment ranging from 13.5 inches at Micheldever to 8.5 inches at Alice Holt. Most crops are satisfactory, but heavy weed growth on some of the Dean sites, and severe frost damage at Alice Holt in the early years, have been adverse factors.

Summary of Observations

SURVIVAL

In the absence of knowledge about weeding, survival figures tell us little. After twenty years the lowest stocking in the experiments is still over 650 per acre (not counting suppressed or dying trees). The great majority of plots have stocking figures of over 1,000 per acre. Except where weed growth has obviously been very heavy, distribution is usually satisfactory. Bunch plantings are all very successful as regards distribution of the crop; few planting points are vacant. This may be because bunches are easier to find in weeding and so are less liable to be cut off.

HEIGHT GROWTH

In all the experiments comparing planting distances of single plants there is not one where differences in height growth, at any stage up to twenty years of age, can be attributed to spacing. The plots in all experiments are remarkably even in height.

However, bunch plantings and more particularly bunch plantings of six, may exhibit better height growth than plots of single plants. Five experiments compare bunch plantings at 4 ft. × 5 ft. or 4 ft × 4½ ft., with single plants at relatively close spacing, 4 ft. × 2 ft., 3 ft × 2 ft., or 4 ft. × 1½ ft. Three of the experiments show a fairly distinct advantage to the bunch plantings, the other two are quite negative. The former three are all in the Dean and Dymock areas, and some common factor connected with weed competition suggests itself as a likely explanation. The three positive experiments have a common seed origin (East Anglia), while the two negative ones have other origins, but provenance explanation seems most improbable. The effect is almost certainly not primarily a spacing one.

GIRTH

Girth at twenty years of age is closely related to spacing; the following figures are typical:—

Forest and Expt. No.	*Spacing in feet*	*Mean Breast-Height Girth of dominants and co-dominants* (1948)*—inches*
Micheldever	4 × 1	11.7
(Expt. 2, P.28)	4 × 2	11.9
	4 × 4	12.4
Dean, Pritchard's Hill	4½ × 1	11.6
(Expt. 3, P.27)	3 × 2¼	11.8
	4½ × 2¼	12.4
Micheldever	4 × 1½	11.7
(Expt. 3, P.28)	4 × 3	15.1

SUPPRESSION OF BRANCHES

The degree of suppression of branches is of course a function of spacing. The following table illustrates the effect:—

Spacing in feet	*Height of lowest living branch after 22 years—feet*	
4 × 1....	10.8	
4 × 2....	9.6	
4 × 4....	8.1	(Means of experiments No. 8 Soudley, Dean, and No. 2 Micheldever)

We have no measurements of branch knots, but the effects of spacing on branch suppression will become progressively smaller now that all crops are in close canopy, and at the twenty-second year the differences are probably already decreasing. The retention of branches of various diameters on trees in canopy is being studied at present at Crumblands, Tintern Forest, Monmouthshire.

FORM

We have attempted to evaluate the crop arising from different spacings by marking down and classifying all dominants and co-dominants (only) in each plot. The classes are arbitrary and somewhat subjective, but have been applied through the whole series by the same team. Class I comprises trees having straight stems, well-defined single leaders, and branches averaging less than half the main stem diameter (observed in the lower live crown). Class II have well-defined single leaders, but deviation of stem from main axis of from two to four inches; branches as in Class I. Class III have forks sufficiently marked to endanger the main leader. All other trees fall in Class IV.

It is difficult to express the results other than in tabular form and by grouping these spacings, which have a comparable range of stockings. Counts vary greatly from experiment to experiment and site to site. The table below only purports to show the pattern.

FORM CLASSES OF OAK PLANTED AT VARIOUS SPACINGS

Table 13

Spacings in feet	Total Number of Expts.	Number of trees per acre at planting	Number of trees per acre in each Form Class at average age of 20 years I	II	III	IV
4 × 1	5	10,890	313	172	565	413
4½ × 1	2	9,680				
4 × 1½	4	7,260	204	129	625	549
3 × 2	5	7,260				
3 × 2¼	4	6,453				
4 × 2	7	5,445	239	111	516	406
4 × 2¼	1	4,840				
4½ × 2¼	2	4,302				
5 × 2	1	4,356				
4 × 3	2	3,630	106	168	221	984
4 × 4	2	2,723	100	150	360	763
4 × 4½ bunches	2	7,260	226	219	410	579
4 × 5 of	2	6,534				
4½ × 5 3	1	5,808				
4 × 4½ bunches	2	14,520	234	192	492	507
4 × 5 of	2	13,068				
4½ × 5 6	1	11,616				

Class I trees can be considered desirable constituents of the future crop, and certain Class II trees are doubtless acceptable and may in time be indistinguishable from what now appear to be better stems.

On the average we do not fall below a stocking of 100 Class I stems per acre in our widest spacing for single plants (4 ft. × 4 ft.)

Assuming that a final crop of 15-inch quarter-girth, with a clean timber height of thirty feet is required, then in 100 years time it will be necessary to have fifty Class I trees on each acre of ground.

To give thirty feet of clean timber it is essential that these twenty-year old trees should keep their "through axis" for another ten years or so, their present height increment being just over a foot a year.

No data are available to show how many of these 100 Class I trees will in fact continue their straight growth to a height of thirty feet, but it would be unsafe to assume that more than 50% will do so.

This would be adequate if their distribution were ideal, but this is rarely so, and some acceptance of what are now classed as Grade II stems will often be necessary at the wider spacings. However, given a good site and satisfactory tending, there appears to be no reason to be afraid of 4 ft. × 4 ft. spacing, and as it has turned out, it is, perhaps, unfortunate that even wider spacings were not tried.

It is clear that spacings of less than 4 ft. × 2 ft. are quite wasteful. The ungrouped statistics suggest that 3 ft. × 2 ft. is a bad spacing, probably because it is difficult to weed without risk of cutting off young plants.

Bunch plantings have shown up relatively well, more particularly as regards distribution of Class I stems. There is a decided (but doubtfully economic) advantage in bunch plantings over single plantings at wide centres. There is no commensurate advantage in increasing the bunch from 3 to 6 plants.

Other Observations

AGE AND TYPE OF PLANTS USED

Comparisons occur in a number of experiments, but never without the complication of different seed origin. There is, however, more than a suggestion that transplants have given better crops than seedlings on very weedy sites.

ORIGIN OF SEED

A number of different seed sources have been used throughout the series of experiments. Comparisons inside experiments are always confounded with age and type, but occasionally differences in mean height and quality of crop appear large enough to be attributable to race rather than the initial advantage of the larger plant, e.g.:—

Forest and Expt. No.	*Spacing in feet*	*Origin of Seed and age when planted*	*Mean Ht.* (1944) *feet*	*Stocking of Class I Stems per acre*
Micheldever	4 × 3	Bavaria (1+1)	19.5	218
(Expt. 3)	4 × 3	Chiddingfold (1+0)	18.0	99 (4 replications)

FORM AND FROST DAMAGE

In spite of the fact that the Alice Holt series were repeatedly and apparently seriously damaged by late frosts during their early history (probably to a greater extent than any other series), they have produced easily the highest proportion of desirable stems, though height growth has suffered. It appears distinctly probable that this high proportion of desirable stems on a site very prone to frost damage has a connection with seed origin, but we cannot follow the observation any further as the seed source (Windsor) was not used elsewhere in these experiments.

SUMMARY

To summarise, the following points emerge, from a study of the available data:

(1) All spacings closer than 4 ft. × 2 ft. are definitely wasteful.

(2) The widest spacing used, 4 ft. × 4 ft., appears capable of giving satisfactory crops, given suitable sites, and adequate tending, and perhaps seed of good source.

(3) Spacing does not affect height growth, at least within the range under investigation.

(4) As between a 4 ft. × 1 ft. and a 4 ft. × 4 ft. spacing, mean girth may be increased in the wider spacing by something of the order of 6% after twenty years growth.

(5) Height to the lowest live branch is greater in spacings of 4 ft. × 1 ft. by some 2 ft. to 3 ft. than in spacings of 4 ft. × 4 ft. after twenty years growth.

(6) Bunch plantings at wide centres such as 5 ft. × 4 ft. have given better stocking and distribution of desirable stems than wide spacing of single plants, and they compare favourably with medium spacings such as 4 ft. × 2 ft., but at a slightly greater expenditure of plants. There is no commensurate advantage in increasing the number of plants in the bunch from 3 to 6.

SPACING EXPERIMENTS IN CONIFERS

By A. M. MACKENZIE

Assistant Mensuration Officer

The earliest spacing trials were established in Forestry Commission plantations between 1921 and 1924. These were assessed in early life, inspections being largely confined to observations on survival, beating up, weeding costs, etc.

In 1935-1936 the scheme was greatly extended, and the bulk of the experiments were laid down at this time. They were carried out by Conservancies at the request of the Research Branch, plants being obtained from normal allocations and local Conservancy procedure adopted in planting.

Spacings used

In the earlier spacing trials (P.21-24) spacing ranged from 3 ft. to 5 ft., but all the 1935/36 experiments were laid out at spacings of 3 ft., 4½ ft., 6 ft., and 8 ft., except for European larch, Japanese larch and Douglas fir in England and Wales, where three spacings of 4 ft., 6 ft., and 8 ft., were used.

In all, 145 experiments were established.

An inspection and assessment of all these experiments, showing their condition prior to brashing, was started in May, 1949. It was then found that 31 experiments had completely failed and that 26 were in such poor shape that they also may have to be written off. Eighty-six experiments, less than 60 per cent. of the whole, were therefore suitable for assessment.

The chief causes of complete or serious failure were fire, lack of weeding, frost damage and exposure. Variable soil conditions within plots rendered many of the plots useless for assessing, or very difficult to assess satisfactorily.

First Assessment

This dealt with:—

1. Height growth
2. Closure of canopy
3. Branch suppression
4. Suppression of ground vegetation
5. Survival
6. Health of crop.

HEIGHT GROWTH

Comparison of individual experiments was on the whole inconclusive, due largely to variations in soil and in stage of growth and development. Average figures for all experiments, however, show that up to this stage spacing has had no significant effect on mean height within the range of spacings tried.

CLOSURE OF CANOPY

Canopy closes earliest in the closest spacings, as one would expect, and the suppression and eventual death of branches and ground vegetation being dependent on this, all three are closely co-related.

SURVIVAL

In general, survival and health of crop are independent of spacing while the crop is in the free-growing stage, although on exposed sites close spacings seem best, probably as a result of mutual shelter. In European larch die-back areas, however, the closest spacings have been the more severely damaged.

Second Assessment

Seven areas in Scotland were selected for a more detailed assessment by reason of the fact that they were in the main adequately stocked, and that one at least of the spacings in the series required thinning treatment. The data were amplified from experiments in England and Wales where sample plots had been established.

The chief points considered in this assessment were effect of spacing on:—

1. Height
2. Crown depth and spread
3. Branch diameter
4. Stem taper

HEIGHT

The data confirm that planting distance had no important influence on height growth.

CROWN DEPTH AND SPREAD

In a number of wide spacings, branches were alive to brashing height and therefore crown depth in the 1935/36 experiments had a wide range. With denser canopy however, the lower branches even in the widely spaced plots rapidly die off, and the overall crown percentage tends to equalise in all spacings with age, as shown by the 1921 to 1924 experiments.

There was considerable interlacing of branches in the close spacings, and this produced their denser canopy. It was found that where planting distance was doubled it induced a 30% increase in branch spread.

BRANCH DIAMETER

Average branch diameter measured at the nearest whorl to six feet height increased with wider spacing, and although no further increase in size will take place after the canopy closes, the heavier branches will persist longer and so reduce the amount of clean timber.

STEM TAPER

Stem taper in the younger experiments was greater in the 8 foot than in the 3 foot spacings. Trees in the close spacings had a more gradual taper and a consistently higher timber height. With canopy closure and increasing crown competition, the experiments of 1921 to 1924 showed that taper in the widest spacings diminished rapidly.

STUDIES OF GROWTH AND YIELD

By F. C. HUMMEL
Mensuration Officer

Establishment and Re-measurement of Sample Plots

During the period 1st April, 1949, to 31st March, 1950, 45 permanent sample plots were established and 95 were re-measured. This compares with 102 establishments and 26 re-measurements in the previous year. Particulars of the plots concerned are summarised in Table 14.

THE ESTABLISHMENT AND RE-MEASUREMENT OF PERMANENT SAMPLE PLOTS

Table 14

	England	Scotland	Wales	Total
Plots in being 1st April, 1949	167	156	63	386
Plots established 1/4/49 to 31/3/50	22	23	—	45
Plots written off	—	4	—	4
Plots in being 31/3/50	189	175	63	427
Plots re-measured 1/4/49 to 31/3/50	56	39	—	95

Of the twenty-two new plots established in England, there were seven each of Scots and of Corsican pine, all of which, with the exception of a Corsican pine plot at Gravetye Forest in Sussex, were established in East Anglia. The reason for adding to the considerable number of pine plots previously established in that area was that the old plots there are thinned either very heavily or very lightly, but there are very few which are thinned to the intermediate grades most commonly used in practice. This deficiency has now been remedied. The only other new conifer plot in England was established in a forty-nine year old stand of Sitka spruce at Gravetye. Of the other new plots, three are in oak, three in ash and one in sycamore.

The twenty-three new sample plots in Scotland are all coniferous and cover ten species. There are eight plots of Sitka spruce, three of Norway spruce, two each of Japanese larch, hybrid larch, Scots pine and Douglas fir, and one

each of Corsican pine, *Pinus contorta*, *Abies grandis* and *Abies nobilis*. The majority of these new plots are in the area around Benmore Forest, Argyll, and along the Caledonian Canal.

The re-measurements included some of our oldest conifer sample plots in England and Scotland, among them the three Corsican and Scots pine plots in the New Forest (E.102, 103 and 104) which are more than eighty years old, and the two seventy year old Douglas fir and Sitka spruce plots at Benmore in Argyll, (S.84 and 98). The *current* annual increment in two of the New Forest plots was found to be still well above the *mean* annual increment, while in the Benmore plots and the third New Forest plot it had fallen below this level. In all these five plots, however, the current annual increment during the past few years still averaged 100 hoppus feet over bark, or more, per acre. These figures are encouraging, and suggest that the rotations envisaged by some foresters are too short, at any rate under certain conditions. We have so much forest land which needs to be replanted, that we cannot afford to add to it areas which are still producing 100 hoppus feet a year, particularly if this increment is being put on by valuable large trees and can be removed periodically in thinnings.

A note was published* on the 1946 re-measurement of the Scots and Corsican pine plots in East Anglia. The re-measurement carried out in 1949 has added little to the information given in that note, except with regard to those plots which in 1942 had been given the abnormally heavy thinning described as "distributive", and had not been thinned since. In the majority of these plots trees have been killed by *Fomes annosus*, in some so many that the plots have had to be abandoned; in others, casualties have been fewer, but the current volume increment has nevertheless been reduced considerably. In the few plots, however, where the drastic reduction of stems in 1942 from about 1,600 to 400 per acre at a top height of little over thirty feet was not followed by damage from *Fomes*, current annual volume increment, which had dropped considerably during the period immediately following the thinnings, has again increased, and is approaching the increment of the plots which have been subjected to normal thinnings at three to four yearly intervals.

The comparative thinning series that were re-measured during the year under review included the two Douglas fir plots at Beauly in Inverness-shire (S.37, 38), which at an age of forty-two years have reached top heights of nearly 100 feet. Total volume production per acre has been 11,400 hoppus feet over bark in the lightly thinned B grade plot and 10,800 hoppus feet in the heavily thinned D grade plot. A note on these interesting plots has been prepared for publication.†

The five Scots pine plots at Bagshot in Surrey which have been subjected to different thinning treatments for twenty-nine years, were re-measured and thinned for the first time since 1941. The results from this series, which are summarised in Table 15, are not very conclusive; but they suggest that the effects of the different thinning treatments on height growth, volume increment per acre, and on the average diameter increment of the one hundred largest trees per acre, are not great. If anything, the unthinned plot and the plots subjected to a light crown thinning seem to be slightly inferior to the others in respect of these three characters.

The average girth of the 100 largest trees per acre in the unthinned plot with its stocking of 896 per acre is now 1.63 times what it was in 1921, while in the heavily thinned D grade plot with its stocking of only 206 trees, the equivalent figure is 1.82. The figures for the other plots lie between these limits.

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* *Forestry*, Vol. XXIII, No. 2, 1950

† *Scottish Forestry*, Vol. 4, No. 4, 1950

THE BAGSHOT SCOTS PINE PLOTS—SUMMARY OF MEASUREMENTS

Table 15

	Date	Thinning Grade				
		Unthinned	Low Thinnings			Crown thinnings
		A.	B. (Light)	C. (Moderate)	D. (Heavy)	L.C. (Light)
Age in years	1921	35	35	35	35	34
	1950	64	64	64	64	63
Average height of 100 largest trees—feet.	1921	35½	35½	40	38	38½
	1950	50	53½	62	58½	55½
Number of stems per acre	1921	2,590	2,515	2,375	1,755	1,545
	1950	896	622	317	206	427
Total volume production incl. all thinnings, in hoppus feet over bark, per acre.	1921	878	943	1,431	1,286	1,610
	1950	2,720	3,524	4,451	4,092	3,840
Average breast height girth of 100 largest trees, in inches.	1921	17½	18	20	19½	21
	1950	28½	31	34½	35½	35½
Average breast height girth increment of 100 largest trees, in inches.	1921	—	—	—	—	—
	1950	11	13	14½	16	14½
Girth of 100 largest trees in 1950 expressed as a fraction proportion of the similar girth in 1921.	—	1.63	1.72	1.73	1.82	1.69

These results suggest that where growth is slow and the first thinnings have been somewhat delayed, the opening up of the canopy does not stimulate girth increment by as much as is sometimes assumed.

The plots of broadleaved species that were re-measured included the oak plot at Salcey Forest, Northants, the mixed plot of ash and beech at Boughton Estate, Northants, the two sycamore plots at Friston Forest, Sussex, and the four Black Italian poplar plots at Rendlesham Forest, Suffolk, two of which have already produced over 1,400 hoppus feet over bark per acre at an age of only thirteen years.

Four plots had to be written off during the year. They were the two Sitka spruce plots S.9 and S.73 at Drumlanrig Estate (Dumfries-shire), the *Thuja plicata* plot S.26 at Dalbeattie Forest (Dumfries-shire), and the mixed plot of Sitka spruce and Norway spruce on Dunach Estate, Argyll, (S.57). The loss of all these four plots resulted from the cumulative effect of wind damage over a number of years. No plots were lost in England and in Wales.

Mensurational Methods

No modifications or additions to sample plot procedure were introduced, but the classification of tree classes and thinning grades which has now been in use for some time, was slightly re-worded for inclusion in the Forest Terminology that is being prepared by the Empire Forestry Society. The

need for publication at an early date of a complete code of our sample plot procedure was emphasised by requests for particulars of our methods from universities in Britain and research stations abroad, and it is hoped to prepare such a paper during the current year.

Further trials were carried out with the eight inch base range finder, the use of which, as a dendrometer, was described in the *Report on Forest Research for* 1949, (page 8). These trials have proved very successful, and it has been decided to modify the existing prototype so that diameters and basal areas can be read directly, instead of having to be determined from the range finder by means of auxiliary tables. This modification will extend the use of the instrument beyond sample plot work to large scale forest enumerations. The dendrometer is not much heavier than a large pair of binoculars and can easily be carried about.

The prototype of an instrument called the "Relascope" which was designed by Dr. W. Bitterlich of the Austrian Forest Service, was also tested and a note describing these tests has been prepared for the *Empire Forestry Review*.* This instrument enables the basal area per acre to be determined from a single count of stems which appear larger than a sighting device on the instrument, and it also enables a direct reading of the "form co-efficient" of a tree to be made, which, multiplied by the cube of the breast-height diameter, gives the volume. The instrument promises to be useful for rough estimates of the growing stock.

Volume Tables

Work was continued on preparing general colume tables for Scots pine, Corsican pine, Sitka spruce, Norway spruce, European larch, Japanese larch, Douglas fir, oak, beech and birch.

The conifer volume tables give average hoppus volumes over bark for trees with a given breast-height quarter-girth and total height. Breast height is measured at four feet three inches above ground level (on the upper side of the tree on slopes), and volumes are reckoned from ground level to an over bark diameter of three inches, this whole length to timber height being treated as one section. No allowance is made for the stump, and branch wood of all dimensions is ignored. This procedure differs slightly from that adopted in the hardwood volume tables. The latter are based not on total height but on timber height, which in broadleaved species is taken to a top diameter of five to six inches, or to the point where the stem loses itself in the crown, whichever comes first. Moreover, in broadleaved species the volume is calculated in lengths by stops instead of in a single length.

The material from which the volume tables for the coniferous species were compiled, came from three main sources:—

1. Temporary sample plots established mainly between 1917 and 1919, for the purpose of preparing the provisional yield tables published in Forestry Commission Bulletin No. 3.
2. Measurements taken in the course of fellings during the first and second world wars by the Timber Supply Departments, Forestry Commission, and the University Research Parties who kindly put their data at our disposal.
3. The permanent sample plot records of the Forestry Commission.

In addition to the main tables giving volumes to a three inch top diameter, several subsidiary tables were prepared showing the volumes to top diameters

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* *Empire Forestry Review*, Vol. 29, 3. 1950

of six, nine, and twelve inches respectively, and the percentage of the total volume that the volumes to these limits represent. There are also tables giving the average stem lengths to diameter limits of three, six, and nine inches respectively, and the volume of bark expressed as a percentage of the over bark volume.

While all the three sources of material listed above were used in the production of the main tables, it was deemed advisable to prepare the subsidiary tables exclusively from our permanent sample plot records, which alone gave the necessary girth measurements at ten feet intervals up each tree, starting at five feet above ground level, and the bark thickness at these points. The bark thickness was determined by means of a Swedish bark gauge. Had the bark percentage table been calculated from the bark thickness at half timber height alone, a slight under-estimate would have resulted because the bark constitutes a smaller percentage of the sectional area of a tree at half timber height than at points nearer to the top or the butt.

The tables for the broadleaved species have been prepared from measurements taken on felled trees in timber yards, felling areas and sawmills all over Great Britain. They must, however, be considered as provisional and subject to revision because they are insufficiently supported by measurements in the largest size classes, and also because a slight bias may have been introduced through having to estimate the position of breast height on stems that had already been felled.

By the end of March, 1950, the tables for oak, beech, birch and Scots pine had been submitted for publication. Each table will appear as a separate Forest Record. The other tables are all nearing completion.

The methods adopted in the preparation of the volume tables differs somewhat from those used elsewhere, and will be described fully in a separate publication. They follow the lines indicated in the *Report on Forest Research for 1949* but with various modifications which were subsequently found to be desirable.

Determination of Volume and Increment in The Census of Woodlands of Great Britain

One of the major tasks during the year under review was to complete the estimates of the volume of standing timber in Great Britain, and of its increment. The estimates are based on a stratified random sample of approximately seven thousand one-tenth acre circular plots, and the methods used are described in a paper submitted to the third World Forestry Congress, while a summary of the actual estimates will be included in the fiducial census reports to be published later. A preliminary analysis of the volume data has shown the fiducial limits (5% probability) of the sampling error to be ± 2 per cent. for the country as a whole, but for individual regions, species or age classes, the errors were of course considerably greater.

Increment of "Free-Grown" Oak

An investigation into the rate of growth of free-grown oak was carried out with the object of getting some preliminary information on the subject, and as a basis for planning a more detailed long-term investigation. The subject is of some importance: firstly, because the rapid depletion of our remaining stocks of large-sized hardwoods forces us to stimulate diameter increment in immature stands as much as possible; secondly, because there are many incompletely stocked, immature areas for which we must know the minimum stocking that will provide a worthwhile crop at maturity.

Several hundred free-grown oak trees, mainly in the Midlands and Southern England, were examined, and their rate of growth and crown diameters

compared with our permanent oak sample plot records and with the figures given in various Continental yield tables. The main points that emerged were these:—

(1) Timber height in free-grown oak is usually low, and in order to obtain a satisfactory length of clean bole, green pruning is essential. Timber height, however, varies greatly and reaches up to fifty feet in individual trees; it does not appear to be closely correlated with the rate of height growth.

(2) The average crown diameter in feet (C) of free-grown oak trees is approximately equal to twice the breast-height quarter-girth in inches (G) plus a constant of 4, i.e., $C=2G+4$. This relationship does not seem to vary appreciably with age, nor with the rate of height and diameter growth, although the crowns of individual trees do of course differ considerably from these average values. It was therefore possible to estimate the maximum number of trees of any specified average girth that can be maintained, under conditions of free growth, on one acre. The number at square spacing is given by the equation $N = \frac{43{,}560}{(2G+4)^2}$, where N is the number of trees per acre and G is the average breast-height quarter-girth in inches.

(3) Stem analyses of several hundred trees indicated that exceptional free-grown oak trees may reach breast-height quarter-girths of twenty-five inches in a hundred years, and that averages of about twenty inches may be expected at that age on favourable sites. It was also found that the current volume increment of individual trees usually culminates long after 100 years, so that it probably pays to keep free-grown oak trees up to 150 years or even more if they are healthy.

(4) By combining the information on the relationship between crown diameter and breast-height quarter-girth with that on the rate of growth, it was possible to construct a preliminary yield table for free-grown oak in Britain. For quality Class II (there are likely to be very few quality Class I sites as defined by this table) the figures for yield per acre at a hundred years are as follows:—

Final yield—1,460 hoppus feet over-bark, spread over 26 trees with an average timber height of 28 ft. and a breast-height quarter-girth of 20 inches.

Intermediate yield from thinnings after the 50th year—1,250 hoppus feet over bark derived from trees ranging between 11 and 18 inches breast-height quarter-girth.

(5) A very small number of young trees per acre is sufficient to achieve complete stocking at maturity. In quality Class II, 26 trees per acre will form a complete growing stock at one hundred years.

(6) At any given age the girth of free-grown oak trees is likely to be at the very most 1½ times the average girth of oak grown under conditions of dense high forest. Usually the difference is less.

Sampling of Thinnings

The cost in time and money of measuring small thinnings is high in relation to the comparatively low value of the produce. An investigation was therefore carried out into the precision that could be obtained by measuring a sample

instead of measuring all thinnings in a compartment. Seven blocks each five to six acres in area were used in this experiment, two at Kinellar, Kirkhill Forest, near Aberdeen in the East Conservancy of Scotland; one in the Forest of Ae, Dumfries-shire, Scotland; two at Thetford Chase in East Anglia, and two at Fernworthy in Devon. A wide range of site conditions and species was thus covered. Thinnings were marked and felled by the local staffs and measured by a Special Duty Party. Several methods of sampling were tested, including the use of selected and random circular groups, and the systematic sampling by rows and single trees. It was found that the subjective methods which involve the exercise of judgement were no more precise than objective random or systematic sampling, and as might be expected, showed a serious tendency to be biased. Of the objective methods the systematic sampling by rows, or, in the absence of rows, of all thinnings along predetermined lines at equal intervals, gave unbiased results of specified precision at minimum cost. The difference in precision however, between the various methods tried was not very great, and the main advantage of sampling by rows compared with other objective methods, is its simplicity. Table 16 is reproduced from a note on this experiment which is being prepared for publication, and it shows the magnitude of sampling error that may be expected if sampling is done by rows under conditions similar to those in which the experiment was carried out.

CO-EFFICIENT OF VARIATION IN THE SAMPLING OF THINNINGS

Table 16

Co-efficient of variation	Number in sample and (sampling fraction) required for populations of :				
	100	500	1,000	5,000	10,000
1%	97 ($\frac{1}{1}$)	470 ($\frac{1}{1}$)	910 ($\frac{1}{1}$)	3,300 ($\frac{1}{2}$)	4,800 ($\frac{1}{2}$)
5%	80 ($\frac{1}{1}$)	225 ($\frac{1}{2}$)	280 ($\frac{1}{4}$)	370 ($\frac{1}{14}$)	400 ($\frac{1}{25}$)
10%	50 ($\frac{1}{2}$)	85 ($\frac{1}{6}$)	90 ($\frac{1}{11}$)	100 ($\frac{1}{50}$)	100 ($\frac{1}{100}$)
15%	30 ($\frac{1}{3}$)	40 ($\frac{1}{12}$)	45 ($\frac{1}{22}$)	45 ($\frac{1}{110}$)	45 ($\frac{1}{222}$)
20%	18 ($\frac{1}{6}$)	23 ($\frac{1}{22}$)	25 ($\frac{1}{40}$)	25 ($\frac{1}{200}$)	25 ($\frac{1}{400}$)
25%	13 ($\frac{1}{8}$)	15 ($\frac{1}{33}$)	15 ($\frac{1}{67}$)	15 ($\frac{1}{334}$)	15 ($\frac{1}{667}$)
30%	10 ($\frac{1}{10}$)	10 ($\frac{1}{50}$)	10 ($\frac{1}{100}$)	10 ($\frac{1}{500}$)	10 ($\frac{1}{1,000}$)

There is a probability of approximately two to one against a sampling error being greater than the variation co-efficient, and twenty to one against it being more than twice as great.

Conversion Losses in Small Thinnings

Another difficulty experienced in determining the volume of small thinnings is that for purposes of records, and for paying piece-work rates for felling, the volume of thinnings is determined from mid-girth and length, while after

conversion into pit wood, Smith's* tables are often used. Careful measurement of several thousand poles of Scots and Corsican pine at Thetford Chase confirmed that the taper of one-inch diameter for every seven feet of length which is assumed by Smith's tables, is very accurate for young Scots and Corsican pine, but that the application of these tables nevertheless gives under-estimates ranging from ten to twenty-five per cent., owing to the fact that the average actual top diameters of the pit props are usually about 0.3 inch more than the minimum specified for each size class. The apparent loss in volume thus caused is greatest in the smallest size classes, i.e., those with top diameters of $2\frac{1}{2}$ and 3 inches.

Relationship between Current Height Growth and Volume Production in Conifers

In an attempt to find a simple method of determining the current volume increment per acre in young stands of conifers, the records of all our permanent sample plots were carefully examined. It was found that within a wide range of site quality and of thinning treatments, current height growth can be relied upon to give a fair estimate of the volume increment, usually within ten per cent., and nearly always within twenty per cent. of the true value.

A note† was published on the results of this investigation from which Table 17 is reproduced. The findings of this investigation will also be of use in the revision of our yield tables.

Statistical Work

In the absence of a fully qualified statistician, the Mensuration Section continued to deal with the statistical problems arising from its own investigations and from those of the other sections of the Research Branch. Compared with the previous year both the volume of statistical work undertaken and the range of problems tackled have increased considerably. This was made possible by freeing a Forester who is reading for an external degree in statistics at London University, from his other duties, and putting him full time on to statistical work.

The major computational tasks of the year included the calculation of the sampling errors of the volume estimate in the Census of Woodlands, the preparation of the conifer volume tables, the investigation into the precision of various methods of sampling thinnings, and the design and analysis of nursery experiments for the Silviculturist, South. The latter experiments included, in addition to the usual trials of fertilisers, some intricate weedkiller experiments which presented interesting and difficult problems in analysis, some of which have not yet been wholly solved. Work for the Silviculturist, North, was confined mainly to examining the effect of the sampling intensity on the precision of nursery experiments. While there is as yet too little information on this point for drawing general conclusions, it would appear that the present standard practice of confining assessments to a sample of three half-square-foot grids may often be adequate for determining the mean height, but not for determining the number of seedlings per unit area. Most of the other analyses of Scottish field and nursery experiments were carried out by the staff of Silviculturist, North. This year, for the first time, a limited amount of statistical work was carried out for the new Genetics section at Alice Holt, mainly in

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* *Smith's Pitprop Tables, Home Timber.* The Lumberbook Company, Clevedon, Somerset, 1944. Price 2s.

† *Empire Forestry Review*, Vol. 29. No. 1. p. 58, 1950

VOLUME INCREMENT PER ACRE FOR EVERY FOOT OF HEIGHT GROWTH BY HEIGHT CLASSES AND SPECIES

Table 17

Top height in feet	Volume Increment per Acre, in Hoppus Feet over Bark for every Foot of Height Growth						
	Scots pine	Corsican pine	Sitka spruce	Norway spruce	Japanese larch	European larch	Douglas fir
21–30....	70 (6)	100 (11)	125 (2)	140 (5)	85 (3)	75 (2)	105 (3)
31–40....	105 (7)	125 (18)	145 (16)	175 (9)	100 (15)	100 (13)	120 (9)
41–50....	155 (19)	150 (15)	150 (15)	190 (15)	115 (27)	120 (26)	135 (14)
51–60....	170 (18)	170 (2)	155 (16)	200 (15)	120 (26)	125 (26)	150 (20)
61–70....	170 (8)	170 (8)	155 (6)	220 (8)	135 (15)	120 (17)	160 (23)
71–80....	— —	175 (4)	155 (6)	220 (4)	120 (4)	140 (4)	175 (16)
81–90....	— —	175 (3)	155 (4)	— —	— —	140 (3)	175 (16)
91–100	— —	— —	155 (3)	— —	— —	— —	175 (5)
Total number of plots for each species	49	44	50	28	69	49	59

The numbers in brackets give the number of plots which fall in each height class.

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connection with investigating the correlation between various characters in different provenances of beech. Work for this section is likely to increase considerably.

Dr. D. J. Finney, of Oxford University, was consulted on some of the more difficult problems, and the help given by him is gratefully acknowledged. The paper by Dr. Finney and H. Palca on "The Elimination of bias due to edge effects in Forest Sampling" was published during the year under review (*Forestry*, Vol. XXIII, No. 1, 1949). This paper gives the results of an investigation which was kindly undertaken by the authors in connection with the Census of Woodlands.

Technical Enquiries

Twenty-seven technical enquiries were received and dealt with. Of these, seven originated from within the Forestry Commission, ten from other sources in Great Britain and ten from abroad. They covered a wide range of subjects

and varied greatly in the amount of work they involved; there were, however, few which entailed no more than the writing of a letter and the majority involved a considerable amount of extracting and summarising of data from our permanent records.

FOREST ECOLOGY

By J. M. B. BROWN
Ecologist

Some Noteworthy Stands of Beech

In the course of the past year, numerous mature beech stands have been examined and recorded in many parts of Britain. In accordance with the distribution of natural and planted crops of beech, the majority of recorded stands were in the South of England; relatively few were in the north of England, Wales or Scotland. During the current season's work, all the north and west of Britain are being combed for well-grown, or otherwise interesting, stands. In 1949 a tour of North East Scotland disclosed extensive woods of mature beech, including several of high quality. A review of this survey will be prepared on completion. In the meantime, a short account will be given of four stands of particular interest, three from the southern counties of England and one from Yorkshire.

FRITHSDEN BEECHES

Frithsden Beeches is the name given to a wood of some fifty acres about half a mile south-east of Ashridge Park, Herts., (Ordnance Survey one-inch, sheet 159; grid reference 52/000105). The altitude is 500-550 feet and the general aspect is east, with a slope of 3-5°, but a shallow, dry valley cuts the southern part of the wood from west to east. This wood forms part of the Ashridge Estate, acquired by the National Trust about 1926. The crop is beech, with a few oak ; many of the beech had been regularly pollarded to provide firewood for the mansion, but this practice was discontinued many years ago, so that pollarded and unpollarded trees now form a high forest of beech about 170 years old. The canopy is very irregular and there are many small and large gaps, due to exploitation, natural death and wind blow.

The soil is derived from clay-with-flints; the chalk which underlies this actually outcrops at the east margin of the stand. Generally, examination of the soil profile showed a deep, very flinty, acid clay-loam, usually a dull brown loam on top, changing to a tenacious reddish clay at 30-45 cm. (12-18 inches). In a pit dug in the valley, nodules of chalk were found below 60 cm. (about 2 feet): elsewhere the profile was free from lime and highly acid (pH 3.5 to 4.5). The ground vegetation varies much in relation to light and exposure, but calcifuge plants are conspicuous. Bramble, *Rubus*, is dominant over wide areas; under dense shade only beech leaves are found, while in some of the gaps not occupied by regeneration, bracken or grasses are dominant. Near the south and west edges of the stand, where winds sweep the ground, *Rubus*, beech seedlings and most herbs are absent, and much of the ground is occupied by mosses (*Mnium hornum, Polytrichum formosum, Dicranum scoparium*), with patches of the grasses *Agrostis, Poa, Festuca ovina, Holcus mollis.*

Three sets of measurements were taken of the mature beech, recorded as plots A., B., C. A was near the western extremity of the wood, B in a moderately

exposed position near the centre, and C in the sheltered valley. The data bring out the influence of exposure on height growth and size of beech.

Plot:	*A.*	*B*	*C.*	*MEAN*
Stems per acre	60	Not recorded	45	52
Average girth at 4 feet 3 inches over bark in inches	66	75½	81½	74
Average total height in feet....	101	109	116	109
Average timber height in feet	65	68	70	68
Average height of clean bole feet	17	36	37	30

Height growth of the beech is thus good on the whole; but the form is by no means good, though there are occasional fine stems. It seems likely that the best trees were exploited some years ago, but there is no direct evidence of this. If so, the regeneration, which is the chief feature of the wood, may have had a better origin than the present crop suggests.

This regeneration occurs in groups of varying size and density, standing in small gaps, and includes all sizes from first-year seedlings to sturdy saplings twenty-five feet or more in height. An attempt was made to determine the age of the older groups of saplings, which appear to be twenty-five to thirty years old and may date from the abundant beech mast of 1922. But nearly all ages from thirty years down were represented, and there was no approximate uniformity of age. The regeneration, in fact, bears the impress of having arisen fortuitously whenever gaps were caused by the felling, or natural decay, or overthrow, of individual large trees. Not all gaps, however, are colonised: a few very large gaps are filled, to the exclusion of beech saplings, by a tangle of bracken, bramble, willow herb, etc., sometimes with occasional oak, birch, or sallow. Near the south and west margins, too, where the prevalent winds scatter the leaves and dry the surface soil, regeneration is rare or absent. Thus the Frithsden regeneration confirms the observations made elsewhere in the Chilterns, that where the ground is a little sheltered from the wind, and rodents are kept in check, beech regenerates very freely in gaps, but that large openings must be avoided. At present many of the groups are threatened by competition from the crowns and roots of the big trees, while all are threatened by grey squirrels. It is satisfactory to know that measures are being taken, on behalf of the National Trust, to deal with these two dangers and at the same time to promote further seeding and the growth of the many patches of small seedlings now on the ground.

KINGSCOTE WOOD

This is an extensive beechwood occupying a steep-sided narrow valley in the Cotswold Hills of Gloucestershire. On Sheet 156 of the one-inch map the grid reference to the site of the records is 31/828973. The valley runs from west to east; altitude ranges from 350 to 400 feet on the valley floor to rather over 500 feet, where the steep slope (about 25° for the most part) flattens out and woodland gives way to tillage. The upper part of the south slope gets a good deal of wind; the western extremity, which was not examined, is doubtless also fully exposed; in the valley, however, conditions are rather sheltered. Kingscote Wood was acquired about 1932 by Mr. F. E. Workman of Woodchester, near Stroud. He appreciated the good quality of the trees and carried out a light thinning. There appears to be nothing to show how the wood originated, nor how or when it was thinned before 1932.

The soil of Kingscote Wood is mostly derived from Great Oolite, of which the outcrop occurs on the upper and middle parts of the slope. There are thin

outcrops of Fuller's Earth and Lower Oolite near the foot of the slopes, but, as the surface soil is in most parts derived from hillwash material, these outcrops have probably contributed little to the soils where the beech is growing. The depth of soil varies a good deal, in accordance with gradient of slope and other factors; but, generally, the soils of Kingscote are moderately deep, well-drained, calcareous clay loams, fertile and retentive of moisture. On the crest of the slopes the surface soil is leached; there is no sign of leaching lower down, where the soil is apparently replenished by calcareous material from above and enriched by the annual leaf fall. These soil differences, coupled with the varying amounts of light penetrating the tree layer, account for the great local differences in the ground vegetation. Under full beech canopy, blackberry or bramble, *Rubus*, is generally dominant, but varies much in vigour. With the blackberry are associated numerous herbs which point to the good status of the soil. On the exposed hill crests, where there is some leaching of the surface soil, calcifuge mosses (*Polytrichum formosum*, *Mnium hornum*, *Dicranum scoparium*) are conspicuous. Willow-herb, raspberry and nettle flourish in the gaps.

The beech in Kingscote Wood are less remarkable for height growth than for the very good form, which has by now earned the commendation of numerous interested visitors. Estimates of height were obtained on four sites, two on the south slope and two on the north. These are referred to as sites A., B., C., and D. A. was near the crest of the south slope, rather exposed with signs of surface leaching of the soil. B. was a sheltered site on the south slope. C. and D. were on the north slope, C. higher up, but on deeper soil.

Plot:	*A.*	*B.*	*C.*	*D.*	*MEAN*
Stems per acre:	No record	—	80	70	75
Average girth at 4 feet 3 inches over bark in inches	58	66	56	53	58
Average total height in feet	83	101½	99	97½	95
Average timber height in feet	55	64	58½	60	60
Average height of clean bole in feet	—	—	47	40	43½

The age of these trees is 130 to 140 years (Quality Class II/III). Their outstanding features are the straight cylindrical boles, the symmetrical crowns, with nearly horizontal branches, and the rarity of forking. Rough barked trees occur, but are infrequent: slight fluting was noted on several trees, but cases of severe fluting are very rare. Apart from some patches of *Coccus* infestation, the beech appeared healthy and in vigorous growth.

There is a good deal of regeneration at the east end of Kingscote Wood; groups and patches of saplings from five feet to over twenty feet in height cover much of the ground there, but there is practically no younger regeneration on the intervening ground, or in the rest of the wood. The saplings are, like the parents, remarkable for good form. Unfortunately a thin crop of parent trees was left too long over the regeneration, which has in many places suffered both by excessive shade and by mechanical injury in felling. In addition, rodent (rabbit and squirrel) injury and canker (*Nectria*) are very prevalent in some of the groups. It is particularly unfortunate that these four different sources of injury should be affecting the regeneration of a racially fine stand of beech growing on an excellent site. Kingscote Wood is, however, now subject to careful supervision, and it may be assumed that measures will be taken to make use of the natural advantages of the crop and the site. The great scarcity of young regeneration presents several problems of ecological interest.

After the expected full mast in 1950 an investigation will be made of the local causes of failure of regeneration.

SLINDON PARK

The Slindon Park Estate, situated 3½ miles north west of Arundel, Sussex, was acquired by the National Trust in 1949, under the will of the late Mr. F. J. Wootton Isaacson. The beechwoods, which cover a large area within the park, are remarkable for the height and girth of the trees and the many trees of fine form. Ecologically and silviculturally they are of interest in several respects. The woods were heavily thinned during the recent (1939-45) war. The previous history of the wood is not recorded, but it may be presumed that the crop was carefully thinned, so that Slindon Park is now an instructive contrast to some of the underthinned, but otherwise good, beech stands seen on the South Downs. The age of the large beech in Slindon Park may be put at 200 to 250 years. Ring counts on stumps of thinnings ranged from 160 to 240, and there is evidently a younger age-class, resulting either from natural regeneration, or from a later planting. Black heart was reported in the trees cut during the war, but many of the cut stumps seemed quite sound. The stand is doubtless over-mature, but the crowns of the trees appeared healthy and there were no signs of bark disease or die-back.

Measurements were taken on four sites in Slindon Park two (A. and B.) near the lodge gate at Fontwell and two (C. and D.) about 400 yards north of the gate. The records are summarised below:—

Plot:	*A.*	*B.*	*C.*	*D.*
Trees per acre	35	25	40	55
Average girth at 4 feet 3 inches over bark, in inches	97	104	75	71½
Average total height in feet	116½	114½	97	92½
Average timber height in feet	81½	93	64	58
Average height of clean bole in feet	46½	53	46	42
Height of tallest tree in feet	123	116	114	101½
National grid reference	41/954074	953074	953076	953077

The data clearly show the very good growth in height and diameter in plots A. and B. The average length of clean bole is also outstandingly good, better than that recorded for Kingscote beech (43½ft.). In some respects, however, the beech in Slindon Park are inferior to the Kingscote beech; the boles are not quite so straight and cylindrical, while some of the crowns showed a distorted branching, perhaps indicating overstocking at one time. It will be noted that the beech on sites C. and D. are in every respect inferior to the beech on sites A. and B., though the data for average height of clean bole are still very satisfactory. Examination of the soil showed a fundamental homogeneity on all four sites; namely a deep very flinty, very acid, brown loam, changing from a sandy loam near the surface to a clay loam at considerable depth. Reference to the one-inch geological map showed a raised sea beach, at the 100 foot level, resting on the chalk. Closer inspection of the soil showed that leaching had proceeded farther on sites C. and D., where there was local mor up to 5 cm. (2 inches) thick. These differences were associated with a very distinctive ground vegetation, resulting from exposure to westerly winds on sites C. and D. In the more sheltered parts of the wood, *Rubus* is generally dominant, with honeysuckle (*Lonicera*), ivy (*Hedera*)), wood sage *Teucrium scorodonia*, and the fern *Dryopteris dilatata*: shadier places are often bare, or bear a mossy cover, and bracken is dominant in some gaps. Plots C. and D. were laid out on the slope and crest respectively of a long, low ridge considerably

exposed to the west. From large areas the leaves have been scattered by the wind; there are no shrubs or herbs and the ground is extensively carpeted by calcifuge mosses, of which *Leucobryum glaucum* is much the commonest.

Beech regeneration is negligible in Slindon Park, but steps are now being taken to promote regeneration by thinning. The 1948 mast was abundant there, as in most parts of Britain, and, in March, 1950, numerous shrivelled one-year seedlings were seen in some parts of the wood. There are abundant flowers this year, and the site would be an interesting one for artificial measures to foster regeneration by bramble control and soil cultivation and liming.

The main features of interest of the Slindon Park beech are:—

(1) The remarkably good height growth on what appeared a most unpromising soil. Doubtless the ground water supply is good.

(2) The evidence that beech will make very good growth on highly acid soil (pH 3.8 on top, 4 to 5 below).

(3) The evidence that production of beech of large size depends on sound thinning, by which also the form of the final crop trees can be greatly improved.

(4) The importance of wind in beech woods. When wind gets access to the floor of a beechwood, the leaf fall is scattered and the surface soil rendered too dry for bramble and herbs, which might hold the leaves. Mosses, or in lighter places, grasses, colonise the bare ground. At the same time the surface soil is deprived of the bases which the decomposing leaves would furnish, acidity increases and leaching is promoted. Height growth of the Slindon beech is poorer on the exposed sites. It is interesting to speculate how far this is due to the direct effect of wind on transpiration, and how far to the edaphic changes.

BRAMHAM PARK

The gardens of Bramham Park were designed by the architect of the gardens of Versailles and include some magnificent belts of beeches flanking the main avenues. The park is on the magnesian limestone outcrop, about 10 miles north-east of Leeds in Yorkshire, and the grid reference on the O.S. one-inch sheet is (for the measured group of beech) 44/406416. The altitude is about 250 feet; with a gentle slope to the east. The soil profile showed a good depth of at least 40 cm. (16 inches) moist loam of good structure over the magnesian limestone rubble. Under the beech and natural sycamore, there is a rich and varied ground flora, including *Mercurialis*, *Allium*, *Oxalis*, *Viola*, *Scilla*, *Fragaria*, *Circaea*, *Urtica*, *Myosotis arvensis*, among the commoner species. The beech have not generally grown in close canopy, although in some places they are now far too close for healthy growth. Measurements were taken of ten well-grown trees, with more or less free crowns. These ranged in breast height girth from 85 to 145 inches (average 105 inches) and in height from 107 to 133 feet (average 118½ feet). Averages for timber height, and height of clean bole were 81 feet and 46 feet. The trees are probably about 240 years old, and some of them are decrepit or dying; but it was generally observed that, where they have ample space, the beech look perfectly healthy. Beech regeneration is very local, consisting of patches of small seedlings, mostly three to seven years old, ankle-high, and usually damaged by rabbits; there are very few older saplings. Sycamore regeneration is generally abundant, as in many other Yorkshire beech-woods. The soil surface is excellent for hardwood regeneration, and the beech is evidently restrained by excessive shade and/or root competition under the canopy: the patches of beech seedlings are nearly all in gaps or at the edges of the belts. It is to be hoped that, by admission of more light, combined with rabbit control, means may be found for regenerating naturally these fine trees.

GENERAL REMARKS

These records of four mature beech crops chosen from the results of the survey to date, show that beech of high quality can be grown in many parts of Britain and on a wide range of soils. More than twenty stands have been recorded in which the average top height was 100 feet or more: these include three in Scotland and three in south-west England. Many of the records, however, fall far short of this standard, and it is a main aim of the survey to bring to light the factors which influence the successful cultivation of beech. Information is being gathered about the operation of many factors, climatic, edaphic and biotic. In this report consideration will be given only to soil reaction to which special attention has been paid in the past year.

Soil Reaction and the Growth of Beech

In Britain, most natural and planted crops of beech are found on the calcareous formations of the Cretaceous, Jurassic, Permian and Carboniferous systems. It is widely believed that beech grows best on limestone, and it has in fact been the practice in the Forestry Commission to plant beech mainly, though by no means exclusively, on chalk and limestone sites. Early in the present survey, good beech was noted on clay-with-flints in the Chilterns and on other soils which had every appearance of being distinctly acid. When, therefore, during the summer of 1949, a reliable electric pH meter became available, it was decided to take pH readings of the soil on all sites where detailed records of beech growth were made. These measurements have confirmed the first impression that high quality crops of beech may be found on soils of low pH. For the purpose of this review the soils investigated will be arbitrarily assigned to four classes:—

(1)	Very Acid	pH below 4.5
(2)	Acid	pH about 4.5—5.9
(3)	Neutral	pH about 6.0—7.9
(4)	Alkaline	pH above 8.0

The word "about" is used because in all cases the pH varies a little—sometimes quite a lot—within the profile, from the several horizons of which separate measurements were taken. Chief importance was attached to the horizons where the fine beech roots occur, and profiles with wide changes in pH down the profile have been left out of account. In the comparison of the growth of beech on soils graded according to acidity, stands which were understocked, or very exposed, have also been omitted.

On soils of Class (1) (very acid), about a dozen reasonably well-grown stands of beech were recorded. Some of the soils gave pH readings under 4, at least in part of the profile: e.g., Penn Wood, Bucks., 80 feet at 90 years (clay-with-flints, pH 3.65 to 4.2); Pennyhill, Bagshot, Surrey, 101 feet at over 100 years (Bagshot Sand, pH 3.3 to 4.3); Frithsden, 100-110 feet at 170 years (clay-with-flints, pH 4.1 to 3.8). Some examples of very good height growth are also assigned to this class. The beech in the more sheltered parts of Slindon Park, on an acid gravel, showing a pH range from 3.8 to 4.8, had grown 115 feet in something over 200 years: while an equally old stand of beech on the National Trust's Stourhead property in Wiltshire (Upper Greensand pH 4.0 to 4.45) showed a mean height of 116 feet. Some very poor stands of beech have also been seen on soils of low pH: these were all more or less exposed and strongly podsolised. At the other end of the scale, about ten fully stocked mature stands have been recorded on soils with pH 8 or over (in some cases the mull layer gave a reading of 7.5 to 7.9). These also comprise stands which, in terms of height growth, are rated as very good to very poor. The best are

Sweet Hill, Cirencester (Jurassic) 105 feet at 106 years: West Dean Park, Sussex (Upper Chalk) 114 feet at 125 years: and Worcester Lodge, Badminton, Glos. (Jurassic) 103 feet at about 150 years. On the other hand, mean heights of 80 feet or under were recorded on several sites with south or west exposure.

It is interesting to enquire in which pH classes of soil the tallest beech crops were growing. So far 25 stands have been recorded with mean top heights of 100 feet or over, but for six of these, pH measurements were not taken. Three are definitely in Class 1 (pH under 4.5); two more in Class 1, but on the margin of Class 2; one is in Class 2 (pH 4.5 to 5.9); eight are in Class 3 (pH 6.0 to 7.9) and four in Class 4 (pH over 8.0). In general, Class 2, the moderately acid class, is not as well represented in the whole set of records as might have been expected. The explanation may perhaps be that soils deficient in calcium carbonate become gradually leached under a beech crop, so that the pH is frequently brought below 4.5. That suggests a subject for a long-term investigation.

The data so far collected tend to show that pH as such bears little relation to the quality-class of beech crops: excellent height growth has been recorded on highly acid soils. Soil reaction must be interpreted in conjunction with other soil characters. Acid loams and clays can supply calcium and other bases in greater amount than acid sands. Yet some acid sands have yielded satisfactory beech crops. There is little doubt that, in these cases, the beech were sending their roots deeply into layers richer in lime. Where conditions such as gleying, or a hard pan, or silt, hinder the roots from penetrating to the more basic layers below, poor growth may be expected. While, however, it appears that the reaction of the soil is not correlated with the growth of beech, the possible influence of the beech canopy on the soil, during a rotation of 150 years or more, must not be ignored. Is one justified in assuming that a pH measurement of 4.0, under a 200 year old beech stand, represents the conditions of soil acidity under which the crop grew up? Clearly some measurements at intermediate ages, combined, if possible, with a long-term investigation of soil changes under beech, are necessary to answer this question conclusively.

FOREST PATHOLOGY

By T. R. PEACE
Pathologist

This account of the work carried out during the year is arranged according to the trees concerned, with a general heading to cover diseases attacking a large number of coniferous genera. Miscellaneous matters are dealt with at the end.

Conifers

BOTRYTIS

In view of the hot, dry summer is was not expected that *Botrytis* would be as troublesome as it had been in 1948. This assumption turned out to be only partially correct, for some of the heathland nurseries in Scotland were quite severely attacked, particularly in the autumn. The species most affected were Sitka spruce and Douglas fir, but Japanese larch and *Thuja* also suffered. It seems likely that Botrytis attack will become a regular feature of heathland

nurseries, owing to the late growth and succulence of the seedlings, and the tendency to dense beds. Spraying experiments, with a view to controlling the disease under these conditions, are being planned for 1950.

BRASHING CANKERS

This matter was dealt with in the *Report on Forest Research for* 1949, (page 15) under the heading "Cankers on Japanese Larch", and it is still most important on that species. But very similar cankering has been observed on Sitka spruce. The experiment on different methods of brashing at four times of year has yielded no results, since no cankers have developed. This is not really surprising, as it is obvious that canker would be much commoner than it is actually, if its appearance was dependant solely on method and time of brashing. A similar experiment on Japanese larch in Holland was inspected, and there *Phomopsis pseudotsugae* had developed on many of the trees brashed in the winter, but scarcely at all on trees brashed during the summer. Saw brashing was less affected than brashing done with a billhook or by hitting with a rod,the theory being that it is the bruising below the branch that is responsible for infection. This is borne out by the high percentage of infection of bruises made by a hammer, provided they were made during the winter. The known cases of post-brashing canker is this country were all discovered too late for the pathogen, if any, to be isolated, but the appearance of the cankers is definitely fungal, and it may well be that our disease is the same as that occurring in Holland. It is hoped to get more information by comparing exact brashing dates of neighbouring cankered and un-cankered stands, and if possible by watching recently brashed stands for the first appearance of the disease.

Pines

DYING OF SCOTS PINE ON CALCAREOUS SOILS

The survey of this disease at Allerston Forest in Yorkshire was completed. It appears to be entirely confined to the Oolite limestone, and in many places the boundaries of the limestone and of the disease are concurrent. Most, but not quite all, the Scots pine areas on the limestone are affected to a greater or lesser degree. No definite correlation could be found between the disease and the depth of the soil over the limestone, though there was a tendency for it to be more virulent on shallow soils. This may merely be because the shallow patches are much drier.

FOMES ANNOSUS IN EAST ANGLIA

Mr. Rishbeth, who was working on this disease, has recently taken up an appointment abroad, and most of his work, though written up, still remains to be published. From the practical angle, his most interesting finding was the possibility of preventing the infection of recently-cut stumps by coating them with a mixture of tar and creosote. Creosote alone, lead paint and titanium paint were less effective, and covering the stump with soil actually encouraged the fungus. If stumps can be protected from infection, they will not be able to act as centres of spread by root-contact to surrounding live trees. He also found that infection of stumps was much less if the thinning was done after several weeks of dry weather, the reason, apparently, being that the drought reduced the production of spores by the fungus. This is hardly practicable in an area where continuous thinning is required to keep up with the programme, but stump treatment is being adopted, for the time being, as normal forest practice. An interesting experiment on the inoculation of stumps with *Peniophora gigantea* is in progress. This harmless fungus will often prevent *Fomes* infection of a stump, by getting there first and rapidly decaying

the stump, before *Fomes* has a chance. The object of the experiment is to see if this could be carried out on a practical scale as an alternative to the tar-creosote treatment. It would have the advantage that whereas a stump treated with a surface protectant might still become infected by *Fomes* from below, one rotted by *Peniophora* would be permanently safe.

A meeting was held recently at Santon Downham between Dr. Garratt, who is completing the assessment of Rishbeth's experiment, the Conservator and District Officers and myself, to decide what further work was needed. A partial repetition of the survey is envisaged, mainly to see whether the rate of progress of the disease warrants the cost of the stump treatments, and whether there is, as suspected, an increasing resistance of the tree to the fungus with age.

CANKERS ON CORSICAN PINE

An interesting but relatively unimportant outbreak of cankers on Corsican pine has occurred at Dunwich Forest, Suffolk. The trouble, which is usually on the brashed length, but sometimes extends higher, consists of a large number of small cankers, giving the stem a very rough appearance, leading to considerable resin flow, and making peeling difficult. It is commoner on the "Ursuline" type than on true Corsican pine. It occurs scattered throughout the plantations, and it should be possible to remove most of the affected trees in early thinnings. If it is spreading, it is certainly not doing so rapidly. It has been variously attributed to bad brashing and to the cold winter of 1946-47. In fact the individual cankers have started in almost every year since 1939, and the majority of them have healed over, sometimes almost immediately, so both the possibilities mentioned above are ruled out. At the moment the cause remains obscure.

MELAMPSORA PINITORQUA

A very severe outbreak of this disease on Scots pine has been found at Orlestone Forest in Kent. Early and complete weeding of the alternate host aspen, *Populus tremula*, which occurs as part of the coppice weed growth, has been recommended. Corsican pine does not appear to be affected. This outbreak stresses the importance of avoiding the planting of Scots pine, where aspen is already present on the ground.

DIEBACK OF CORSICAN PINE

The survey of this disease at Allerston Forest, Yorks., has also been completed, but the results have not yet been fully analysed. It is quite certain, however, that it is quite separate from the dying of Scots pine (see above), and that it has no connection with limestone. A very bad outbreak of this trouble was visited at Thornthwaite Forest in Cumberland, and plots were laid out to be used to study the progress of the disease, and to aid in arriving at a decision as to whether the area (about seventy acres in all) should be felled and replanted, or retained.

CRONARTIUM RIBICOLA

Two importations of grafting material of *Pinus strobus*, selected in America as resistant to white pine blister rust, have been made. No success attended the grafts made from material sent in the summer of 1949, but winter grafts with a second lot of material have succeeded in a few instances, and, it is hoped will provide material for further grafting and subsequent trial.

Spruces

DYING OF GROUPS OF SITKA SPRUCE

Assistance was given to Mr. Day of the Imperial Forestry Institute, Oxford, in his excavation of roots of unhealthy Sitka spruce at Harry Hill in the Forest

of Dean. As a result of this work and of later observations made mainly at Kyloe Estate, Northumberland, and Moorburnhead in Dumfries-shire, Mr. Day has given an account of the whole trouble on a physiological basis. This diagnosis seems to leave certain matters unexplained, and Mr. Murray has already started a comparative survey of the known affected areas, with the particular idea of trying to find some explanation of the deaths occurring in groups, rather than scattered throughout the stand, as is usually the case, for instance, with drought damage. A number of affected areas have been kept under periodic observation, each tree being numbered. During 1949 the disease made little progress in these plots.

DYING OF NORWAY SPRUCE

This disease is in direct contrast to the group dying of Sitka spruce. The Norway spruce die from the top down, whereas in the case of Sitka spruce the roots succumb first. It was originally found on Comlongon Estate near Dumfries, where over the last fifteen years it has done a good deal of damage. It has now been found in a number of other areas, and something very similar has been seen in Holland, where it is said to be quite widespread. It has all the appearance of a needle and shoot-attacking fungus; but no one fungus has yet been consistently isolated in Great Britain, and in Holland a fungus which has been isolated from a large number of trees has failed to cause the disease by inoculation. Plots to study the progress of the disease have been set up at Comlongon, and so far the disease has shown only slow extension. Work on the other areas has not yet been started.

Douglas fir

PHAEOCRYPTOPUS GÄUMANNII

Further observations have been made on the numbered trees in Wales and South-west England, but the results have not yet been analysed. Pressler borings have been taken from the stems of some of the trees, to see what effect, if any, the fungus has had on the rate of growth. It is becoming increasingly evident as a result of general observation, that this fungus is responsible to a considerable degree for the slightly sick appearance of much of the Douglas fir in the west of Britain and especially in Wales.

Three areas in Switzerland, where the disease was recorded before the war, were visited in October, 1949. In most cases the trees were still somewhat thin in the crown, and the rate of growth, which fell off about ten years ago, was still rather low. On the other hand there appeared no likelihood of the trees succumbing to the disease, indeed their health was said to be improving. It seems likely, therefore, that the major effect of this fungus will be to slow up the rate of growth, and possibly displace Douglas fir from its position as one of our fastest growing species, rather than to prevent its cultivation.

Thuja

KEITHIA THUJINA

Observations were continued on the plants raised from seed sown in four isolated nurseries in 1948. No definite signs of the disease have yet appeared. Further sowings were made in two of these nurseries, and in four other isolated nurseries in 1950. No further sowings were made in the other two nurseries involved in the 1948 sowing, as they were both too exposed for the raising of good *Thuja*. Most of the plants raised at Devilla Nursery in Fife were large enough to be used for planting as one-plus-one transplants. Though their good condition was mainly a reflection of the fertility of the nursery, it was also due to their freedom from *Keithia*.

Tsuga

BUTT ROT

Several instances of severe butt rot in this species have been reported during the year. Both *Fomes annosus* and *Armillaria mellea* seem to be involved, and in two instances comparable areas on low, damp ground were much less affected than trees on higher drier ground. A case examined at Gwydyr Forest disclosed that nearly all the rot had entered through the stumps of double stems, which had been removed in early thinnings. This stresses the point that, with conifers at any rate, if double stems reach thinning size they should both be left or both removed.

More data are required before any condemnation of *Tsuga* on the ground of its susceptibility to butt rot can be made. It may well be that with *Armillaria mellea* a state of balance may be reached, as has been the case with *Thuja* and the same fungus. Such a balanced existence, with only part of the root system attacked, does not seem to be particularly harmful to the tree. The position with regard to *Fomes* is more disquieting, since that fungus, unlike *Armillaria*, is capable of extending far up the stem of the living tree, and therefore causes a much greater loss of value.

European larch

Inoculations on larch plants on an estate near Penzance were unsuccessful in 1949, but have been repeated in 1950 with four strains of the fungus *Dasyscypha* instead of one. The object of the inoculations is to test the effect of the fungus on healthy larch on a frost-free site.

Poplars

POPLAR TRIALS

Planting was continued at trial areas at Hockham, Thetford Forest, in East Anglia; at Auchencastle, Dumfries-shire; at Dyfnant Forest, Montgomery; and at Hallyburton Forest, near Dundee; and also at the much older trial area at Yardley Forest, Northants. New trials were started at Quantock Forest, Somerset, in a fertile valley site, and at Clocaenog Forest, Denbighshire at 1,100 feet on peat, but in a comparatively sheltered valley. A new area at Harling, Thetford Forest, Norfolk, has been selected, and will probably lead to a reduction in the Hockham trial area, which has not lived up to early expectations, possibly owing to a succession of dry years. Further additions were made to the Populetum in the New Forest. The stool bed at Bedgebury Forest, Kent, has been abandoned, so that now all poplar nursery work, apart from silvicultural stocks at Kennington Nursery, Oxford, is concentrated at Alice Holt and at Fen Row Nursery, Rendlesham Forest, Suffolk. But Mundford Nursery, Norfolk, is being reclaimed, mainly for use as a canker infection area, and part of the land at Harling is being reserved for a nursery to allow for future expansion either of the varietal trials or of the silvicultural work. Manuring has already greatly improved the fertility of Fen Row Nursery, and most of the stock there grew very well during 1949. Eighty-three clones were added to the existing collection of 133, making 216 in all. Some of these are already known to be of no importance and will be discarded, others are required only for botanical or for comparative purposes, and will be relegated to the Populetum and the stool bed. Many of the remainder will be used in the trials, but only if their behaviour in the nursery is satisfactory.

Switzerland was visited in October, 1949, for the meeting of the Permanent Committee of the International Poplar Commission, and again in April for the full meeting of the Commission; on both occasions visits were paid to Swiss

poplar plantations. Two days were also spent with a regional poplar excursion in the south of France. Before the April meeting three days were spent in Westphalia and the lower Rhine Valley with Professor Houtzagers of Wageningen and two Dutch colleagues. During the German tour most of the persons concerned with poplar breeding, research and the official encouragement of poplar planting in Germany were contacted, and a great deal of useful information collected. Some of the information collected on these visits to the continent was used in the preparation of a Poplar Bulletin, which is now in final draft.

A good deal of time has been spent on visits to private estates and Forestry Commission poplar plantings to give advice and to get information on the behaviour of different varieties under various growing conditions. It was definitely established that the very fine stand of poplars at Brahan Castle, north of Inverness, consists of *Populus regenerata.*

POPLAR CANKER

A considerable number of poplars for resistance trial were planted between the rows of cankered sets at Alice Holt. All the plants in this trial were artificially inoculated with bacterial slime in 1950, as well as being exposed to natural infection. A considerable number of exuding cankers developed on the cankered rows and some natural infections have been found recently on the plants under trial. The results of the inoculation will not be available until later in the year.

It is now definite that there are two clones in the country, which are botanically referable to *Populus eugenei.* They differ only in date of leafing and resistance to bacterial canker. One, which comes into leaf nearly as early as *P. robusta,* is resistant to canker; while the other, which comes into leaf at least a week later, is highly susceptible. The susceptible strain is present here and there all over southern England. But the resistant one is so far only known on two estates in Norfolk, and at Kew and Edinburgh Botanic Gardens. Further information on its resistance is required, but it appears probable that it will prove a valuable addition to the poplars available for planting in this country. At Ryston Hall, Norfolk, it is as straight as *P. robusta,* and slightly superior in rate of growth.

Close liaison is being kept with Mr. Sabet at Cambridge, who is doing very useful work on the bacteria causing the disease.

Elm

ELM DISEASE

The annual survey was repeated in 1949, and some of the serial photographs repeated. It is intended to summarise the work done since 1927 on the behaviour of this disease in Great Britain in a publishable form. It has been decided to discontinue the survey owing to pressure of other work. Generally there were fewer active cases in 1949 than in 1948, owing to the depressing effect of the wet summer of 1948 on the beetle population. But, as usual, some areas reported bad outbreaks, presumably owing to local build-ups in the number of beetles.

At the present rate of destruction it seems unlikely that the elm will ever disappear from Great Britain; though it may gradually lose its predominant position in parts of the country.

The experiments in spraying elms with D.D.T. to protect them from beetles and therefore from infection by the fungus gave less definite results than in 1948. The sprayings at Folkestone failed to protect the trees, and at Aldenham, Hertfordshire, the amount of infection on the controls was not great enough to give clear results, though the sprayed trees were certainly less affected. The

experiments have been repeated this year at Aldenham only. Frequent sea winds at Folkestone made it a difficult area for such work.

Inoculations were repeated on the clones surviving from pre-war resistance trials, and those which did not develop the disease were propagated for further testing. Further inoculations have already been made this year, but it is too early to assess their results. Grafts were also made with polyploid elms from Sweden, which have not yet been tested for resistance to *Ceratostomella ulmi*, and also of the rather uncommon native elm *Ulmus plottii*, which has not been sufficiently observed for its natural resistance to be known.

Chestnut

ENDOTHIA PARASITICA

Several outbreaks of disease on chestnut have been visited in case they were found to be due to Chestnut Blight. Fortunately none of them were. Contact has been maintained with workers on this disease in other countries.

INK DISEASE

A further visit has been paid to a rather serious outbreak of this disease at Garnons, near Hereford. Here the usual accompaniment of bad drainage appears to be entirely lacking, and the trees are dying on what would appear to be first class hardwood soil. Further work is required.

Beech

CANKER AND BARK DIEBACK

Mr. Murray, who is working on this problem, is of the opinion that at least two different diseases occur, and probably more. A canker on young beech, particularly prevalent at Westbury Forest, Hampshire, appears to be due to a *Nectria* without any connection with Beech Coccus. On the older trees there may be some connection, and detailed observational records are being kept on a number of trees to see how the disease progresses, and whether the Coccus has any connection with it. Since the investigation started, numerous cases of trouble with beech, particularly the dying of older trees, have come to light.

Willow

WATERMARK DISEASE

Renewed consideration has been given to the possibility of further extension of the Watermark Disease Order and on the certification of set beds.

Proposals for further research on the disease have been prepared and are under consideration.

Sycamore

WANSTEAD SYCAMORE DISEASE

A survey of this disease was made in the summer of 1949, and again this year. It is now known to extend a few miles east of Wanstead, to Plumstead south of the Thames, to several locations on the outer fringe of north London, to Staines and to a point near Guildford. Random survey of sycamore stands in the south of England has so far failed to reveal it in any other area. The causal fungus still remains unidentified. On occasion it can behave as a harmless saprophyte, having been found fruiting on branch stubs on otherwise healthy trees and on sycamore fence posts. On the other hand it appears to be able to kill quite large trees within less than a year from the appearance of the first external symptoms.

Since 200 trees showing external symptoms were felled in Wanstead Park in 1949, a very large number of fresh cases have arisen. Efforts are being made to get all trees known to be actively infected felled and burnt, but so far the discovery of fresh cases has greatly exceeded the number destroyed. It is hoped to make a special appointment for the study of this disease, but so far no suitable person has come forward.

Miscellaneous

Much time has been spent in the field on inspection, advisory visits and on various research projects. Mr. Murray has spent a considerable time at East Malling Research Station, Kent, working with that staff on virus diseases, so as to be better able to work on any suspected virus disease of forest trees that may be found. The Pathologist made a short tour in Wales and East Anglia with Professor Boyce of Yale, and Dr. Hutchins, head of the United States Division of Forest Pathology, during the course of which valuable exchanges of information took place. The two continental visits have already been mentioned, one to Switzerland only, and the other to Holland, Germany, Switzerland and France. Contact was made with Dr. Van Vloten and Dr. Went in Holland, and Dr. Terrier in Switzerland, and diseased areas of Douglas fir, and Japanese larch, in these two countries, were visited.

Lectures on Forest Pathology and on Poplars were given at all the Forester Training Schools.

During the period under review, 137 enquiries were dealt with. Thirty-six of these came from the Forestry Commission staff, etc., and 101 from private estates.

FOREST ENTOMOLOGY

By H. S. HANSON
Entomologist

Larch Sawfly Surveys

The large areas of coniferous plantations now existing in various parts of Britain afford opportunities for the development of numerous pests. Many species of insect, some of which were formerly regarded as being of little economic importance, have begun to cause appreciable damage in some localities. During the last few years, strong infestations of various species of Sawflies have developed in certain districts, and the discovery of a batch of larvae of the Large Larch Sawfly at Radnor Forest in 1948 focused attention on the necessity for studying the records of previous infestations of this dangerous pest, and investigating the present distribution and economic status of this and other sawflies in coniferous areas in this country.

The Large Larch Sawfly, *Pristiphora* (*Lygaeonematus*) *erichsonii* Hartig, is a native of Europe and was originally described by Hartig in 1837 under the name *Nematus erichsonii*. Since that date it has been recorded from various parts of Europe, from time to time, but does not appear to have been a very serious pest in its native habitat, where it is doubtless kept in check by natural control factors.

It was first reported in America by Hagen in 1881. In that year it was found in the Harvard Arboretum, where a large number of trees of various kinds had been imported from all over the world. Subsequent reports, however, seem to indicate that the species had become established in America several years previously. Hopkins (1909) stated "during several extensive outbreaks since 1880 it has killed from fifty to one hundred per cent. of the mature larch over vast areas in the north-eastern United States and south-eastern Canada. It is evident that the amount of merchantable-sized timber that has died as a result of defoliation by this insect will aggregate many billions of feet".

In 1883, Fyles reported its presence in eastern Canada. Two years later, Fletcher (1885) gave an account of its occurrence throughout the provinces of Ontario, Quebec, New Brunswick and Nova Scotia, and in his historical account of its occurrence in Canada subsequent to the year 1882, the same writer (1906) stated: "After three or four years of being stripped, the larches over millions of acres and practically over the whole of eastern Canada were almost wiped out. With this large destruction of its host plants, the insect practically disappeared and little has been heard of it until last year (1905)". In that year indications of a new outbreak were observed and the new infestation developed throughout the greater part of Canada.

The insect attracted little attention in Britain until 1906, when a strong infestation was reported in the Lake District (i.e. parts of the Counties of Cumberland, Westmorland, and Lancashire, in north-west England), but it seems probable that this infestation had then been in process of development over a period of several years, as by that date large numbers of trees over considerable areas had been completely defoliated. As the larvae feed entirely on the foliage of larch trees, its establishment in Britain had doubtless taken place since the host plant was first introduced.

For the benefit of those who are not familiar with the Large Larch Sawfly, and those who do not remember the depredations caused by this insect in larch areas in this country during the early years of this century, a short description of the insect and its life cycle is given, also a brief account of the development of the outbreak and the combination of factors which terminated the infestation. This account is based partly on the reports of the Ministry of Agriculture, who organised a comprehensive investigation in which Lord Robinson, now Chairman of the Forestry Commission (then Mr. R. L. Robinson of the Office of Woods and Forests) played a very prominent part: also partly on reports by the late Dr. C. Gordon-Hewitt, who studied biology of the Sawfly and its natural enemies in the Lake District, and at the Department of Zoology, Manchester University; supplemented by the writer's personal experience when studying under Mr. J. Mangan, who took over and continued the biological investigation when he succeeded Dr. Hewitt on the appointment of the latter as Dominion Entomologist in Canada.

Description of the Large Larch Sawfly

The females vary a little in size but the average length is rather less than $\frac{1}{2}$ inch, and the expanse of the wings is about $\frac{7}{8}$ of an inch. The body is jet black with a broad orange-red band across the abdomen. The saw-like ovipositor projects slightly from the tip of the abdomen. The male is smaller and more slender, but is seldom seen as the proportion of males to females is generally less than four per cent., sometimes less than one per cent. Copulation seldom occurs and reproduction is almost entirely parthenogenetic. This has considerable influence on the abundance and rate of increase of the sawfly population, as the females begin to deposit their eggs shortly after emerging from their cocoons, and there is no dependence upon the presence of the male. The average number of eggs laid is about fifty.

LIFE CYCLE

The eggs are pearly white in appearance and almost transparent; cylindrically oval in shape, and about $\frac{1}{16}$ of an inch in length. They are deposited in slits cut by the ovipositor of the female in the terminal shoots of larch branches and twigs, often on the lower portion of the crown. The eggs may all be laid in a single shoot or distributed over several shoots, but the egg-slits are usually on one side of the shoot and generally near the tip. When a large number of eggs have been deposited in a single shoot, the tip generally wilts, curls over and turns reddish-brown. The presence of sawfly infestation may be detected by these curled and wilted shoots from the middle of summer onwards. The value of this method of locating infestations should not be over-rated. When strong infestations occur they are more readily detected by spotting the clusters of feeding larvae and the damage they cause to the foliage.

The full grown larva measures about $\frac{3}{4}$ of an inch in length. The head is jet black and the three pairs of thoracic legs are also black. The dorsal surface of the body may vary from bluish-grey to greyish-green in colour, except a very narrow band immediately behind the head, which, like the ventral surface, is very pale green. The seven pairs of abdominal feet including the terminal pair are also very pale green. Larval development is normally completed in from three weeks to one month, during which four or five moults may occur. On completing their development the larvae descend to the ground, where they spin brown fibrous cocoons beneath the turf or moss round the base of the tree, or under stones. So far as is known there is only one generation a year, the winter is passed in the larval stage within the cocoon, and transformation normally takes place during the spring of the following year. But the life cycle is not always completed in one year; many larvae may remain unchanged until the second year or even longer.

Date of emergence of the sawflies may also vary very considerably. Early specimens may emerge at the beginning of May and emergence may continue well into August, but the peak of emergence is generally reached by the third week in June and after that there is normally a steady decline. Consequently the date of egg laying also varies, and larvae in all stages of development may be found at any time from the end of May to the end of August or early September, and full grown larvae may be found up to the middle of October. During the 1949 survey a few full grown larvae were found in the Lake District on October 13.

DISTRIBUTION IN BRITAIN

The reports of the investigation carried out during the Large Larch Sawfly outbreak throw much light on the distribution of the insect and its relative abundance during that period, and will be useful in the present instance for the purpose of comparing the trend of population development. Although the outbreak was first reported from the Lake District in 1906, subsequent reports showed that an infestation of similar intensity had simultaneously developed in North Wales, and other infestations of much lighter intensity had developed in other parts of Britain.

During 1909 the Ministry of Agriculture began its survey and population density investigation. Starting with the badly infested area in Wales, a scale of degrees of intensity of infestation was adopted for use in future reports. Four degrees of intensity were defined as follows:—

Intensity I=Very Bad. Some trees already dead, others with crown very thin and practically defoliated in summer. General appearance of trees, moribund. Leading shoots have been attacked.

Intensity II=Bad. No trees dead. Trees badly browned in midsummer. Few terminal shoots of lateral branches produced during current year, dwarf

shoots thereby stimulated to growth, with result that these new shoots have been utilised for egg laying by the sawfly.

Intensity III = Slight. No trees dead. Considerable numbers of the terminal shoots of lateral branches have had eggs laid in them. Little or no browning effect in midsummer.

Intensity IV = Very Slight. No dead trees. Very few of the lateral shoots show signs of attack.

The infested areas were then surveyed and a map was prepared showing the boundary or limit of extent of each intensity of infestation. It was estimated that Intensity I covered only one to two square miles, and that there were up to eight square miles within the zone of Intensity II; while there were four hundred square miles within the third, and fourteen hundred square miles within the fourth zone, or degree of intensity. These figures refer to total areas of land surface and not to actual areas of forest. A similar survey was made of the infested areas in the Lake District, and a skeleton survey was carried out for the whole of Great Britain to a point north of Inverness. A map was prepared showing the approximate degree of infestation throughout the whole country during the year 1910. This map showed that degrees of infestation of Intensity I, II and III were almost entirely confined to north Wales and the Lake District, while infestations of Intensity IV occurred in almost every part of the country where larch crops were present.

At this stage, in many of the more severely infested areas, most of the trees had been killed by repeated defoliation, and in several badly infested areas the dead and dying trees were being felled. In one area alone 15,000 dead trees were felled during 1909.

The subsequent pattern of distribution and density of infestation changed very little in general outline, but there were local changes in the degree of infestation. In some cases where crops destroyed by the sawflies had been felled, the sawflies which emerged in these areas during the following year migrated to neighbouring stands which had previously been less severely infested. This had the effect of increasing the density of infestation within these areas to a higher category of intensity. There was considerable fluctuation in population density in the more heavily infested districts during the next two or three years, but by 1913 there were evident signs that the severity of the outbreak was on the decline and that the collapse of the outbreak was imminent.

CONTROL FACTORS

Although insectivorous birds assisted by other species not normally regarded as insectivorous, such as chaffinches, starlings, rooks, jackdaws, magpies, pheasants and woodpigeons, devoured large numbers of larvae, and many cocoons were emptied by shrews and voles, it is doubtful whether the combined attack of these predators, and of certain species of predatory insects, had any appreciable effect in reducing the enormous population of sawfly larvae in the large and somewhat remote areas in the main centres of infestation.

As the biological investigation proceeded, it was found that the Sawfly larvae were being attacked by parasitic insects. These were first observed in the areas around Thirlmere in the Lake District. The most important of these parasites was an Ichneumoid identified as *Mesoleius tenthredinis* Morley. In certain areas, parasitism by this species was 6% in 1908, had increased to 15% in 1909, and by 1910 was found to be 62% in several localities, one sample of cocoons from the Lake District showed parasitism of 64.7%. In the same year samples of cocoons examined from two areas in Wales showed 33% and 40% parasitism.

Several other species of Hymenopterous parasites were found in the Lake District, also two Tachinid parasites.

A species of parasitic fungus identified as *Isaria farinosa* Fr., also attacked and destroyed the larvae of both sawflies and parasites in many cocoons.

In 1912 it was discovered that a large proportion of the cocoons examined contained the shrivelled remains of larvae which had been killed by what was thought to be some form of bacterial or virus disease. The cold wet weather during that year had doubtless favoured the development of this disease. In 1913 the rate of mortality resulting from the disease was found to be much higher than in the previous year. It seems probable that this disease, together with the combined effects of parasites and other natural enemies, accounted for the collapse of the sawfly infestation in the chief areas concerned.

In the meantime, the Ministry of Agriculture had registered the Large Larch Sawfly as a "Scheduled Pest", and had organised an intensive campaign among private woodland owners throughout the entire country, and every conceivable method of attack was adopted for the destruction of larvae wherever they were found, including spraying with chemicals, grease banding trees, crushing larvae by hand, and the erection of nesting boxes for the encouragement of insectivorous birds. Most of the badly damaged crops were felled and cleared, and with the advent of war in 1914, the majority of the older stands of larch were cleared during the next few years; by 1920 no trace of the insect could be found in Britain. Since then no infested areas have been reported, except that as a result of several days searching the writer found about a dozen cocoons in the Lake District during the winter of 1933 and a few more were found during the following winter.

The results of the 1949 sawfly survey indicate that the present distribution of the Large Larch Sawfly is chiefly in localities in the Lake District and Wales, corresponding roughly with the main centres of infestation in zones of Intensity III during the outbreak referred to above. Batches of larvae were found in Radnor Forest in Wales; Mortimer Forest in Shropshire, and in the Manchester Corporation's plantations at Thirlmere in the Lake District. Infestation at Radnor and Mortimer was very slight, but at Thirlmere the infestation was in a more advanced state of development, and in that locality points of infestation were found scattered over a large area. In each locality both Japanese and European larch were attacked. In the Thirlmere area clusters of larvae were found on forty-eight Japanese larch and on sixty-seven European larch. Several hundred larvae were collected and allowed to spin concoons. From these cocoons, specimens of the Ichneumonid parasite *Mesoleius tenthredinis* Morley have emerged, at the Forest Research Station. This is the chief species recorded during the previous infestation, and provides evidence that parasites have continued to play an active part in the control of the sawfly since the collapse of that outbreak. The present survey shows that the density of the Large Larch Sawfly population in all areas visited in still below that of Intensity III of the previous infestation. A few shoots utilised for egg laying were observed in the Lake Vyrnwy area in Wales, and signs of infestation were found on the Lowther Castle estate in Cumberland, but no sign of the presence of this species could be found in numerous other areas examined in North Wales, the North of England, and Scotland.

Other Species of Larch Sawflies Observed during the Survey

Four other species of larch sawflies were included in the 1949 survey. Particulars of these species and their observed distribution was as follows:—

ANOPLONYX (=PLATYCAMPUS) DUPLEX LEP.

The adult insect is about $\frac{1}{4}$ of an inch in length, and has a wing span of rather less than $\frac{1}{2}$ inch. Head, thorax and abdomen black. Legs almost

white, with variable dark areas on the femora; the tarsi of the hind legs are also dark in colour.

The larva is bright green, with four dark green longitudinal bands extending throughout the entire length of the body, and is about $\frac{5}{8}$ of an inch in length when full grown. In shape, the body is stout in front and tapers appreciably towards the rear. The head is amber coloured, and the eyes are black.

This species was first recorded as a pest of larch in 1947, when strong infestations were reported in hybrid larch plantations in the Forestry Commission area at Craigvinean near Dunkeld, Perthshire, and in Warren Wood on the Atholl Estate in the same neighbourhood. Collectors had previously recorded specimens from various localities in the South of England and from Glamorgan, also from Lancashire (1934), Aviemore, Inverness-shire (1944), and Braemar, Aberdeenshire (1948).

In 1949 the larvae of this species were very numerous at Craigvinean, Warren Wood near Dunkeld, and in larch areas at Blair Atholl. The foliage of many of the trees in these areas was severely damaged and had a scorched appearance. The survey showed that this species was present in all larch areas visited in North Wales, the North-west of England, and in larch areas in all parts of Scotland at all elevations. On the Mar estate near Braemar the larvae were numerous in larch woods up to 1,800 feet elevation, and specimens were found on scattered self-sown larch trees at an exposed point at nearly 2,000 feet elevation.

PRISTIPHORA (=LYGAEONEMATUS) LARICIS HARTIG

This insect, popularly regarded as the only common larch sawfly in Britain, and generally referred to as the Small Larch Sawfly, is about the same size as Anoplonyx. The adult is about $\frac{1}{4}$ inch in length with a wing span of nearly half an inch. The body is black above and below, except the terminal portion of the abdomen which is pale on the underside.

The larva is green, dark along the centre and upper surface and light on the underside. There is a white stripe on each side of the dark central line, and a second white stripe on each side above the legs. On the thoracic legs are a number of small brown flecks, and regular brown spots on the head. The body is fairly regular in thickness throughout, and when full grown is slightly over half an inch in length.

Small numbers of larvae were present in most of the larch areas visited during the 1949 survey, and the insect is probably distributed throughout the whole country, but in no area very numerous.

PRISTIPHORA (=LYGAEONEMATUS) WESTMAELI TISHB.

This Sawfly is about $\frac{1}{4}$ inch in length, with a wing span of nearly $\frac{1}{2}$ an inch. The entire body is black above and very pale below.

The head of the larva is olive green, the body is olive green to light brown (light green immediately after shedding the skin), paler at the sides and beneath. The front and middle segments each have a pair of transverse rows of black spicules, each row with four spicules above the spiracle on each side; below the spiracles are a number of minute black spicules.

This species was first recorded in 1919, when a small infestation was found attacking fourteen year old larch on the Arncliff estate in Yorkshire. It has since been recorded from several localities extending from the South of England, through Wales, and the North of England, to the North of Scotland. During the 1949 survey the larvae of this insect were found in small numbers in several larch areas in Wales and the Lake District, and were fairly numerous in the Grizedale Forest, Lancashire (Compts. 7, 9, 10 and 11, all P.38).

PACHYNEMATUS IMPERFECTUS ZADD.

Nearly $\frac{1}{3}$ of an inch in length, with a wing span of about $\frac{5}{8}$ of an inch. The head is light in colour with a black patch between the eyes; thorax and abdomen entirely black.

The larva is light green with a broad dark green longitudinal band on each side of the body, and a narrow one over the legs. There is a brown speckled area on the front of the head.

Specimens have been recorded from Devon, Surrey, and Hertfordshire. Specimens of the larvae have been found at Alice Holt and at Harling in Norfolk, but during the 1949 survey the species was not found in Wales or in the North of England or in Scotland.

Spruce Sawflies

In the previous year's report reference was made to small infestations of two species of spruce sawflies in several localities in the south of England. The species referred to were *Pristiphora Abietina* Christ and *Gilpinia Hercyniae* Htg. During 1949 larvae of both these species were found in spruce areas in several localities in the South of England, and a small infestation of the former was located at Radnor Forest in Wales.

An infestation of spruce sawfly at Parkhill in the Forest of Dean, which has probably been building up for several years, was reported as *Pristiphora abietina*, but was subsequently identified as *P. subarctica* Forr. =*Lygaeonematus subarcticus* Forr. Formerly it was considered that this species existed only in Swedish and Finnish Lapland as, so far as is known, it had not been recorded from any other locality. An outbreak of this species in Finnish Lapland in 1936 caused widespread destruction in spruce forests. It is evident, therefore, that this insect is a potentially dangerous pest, and very undesirable addition to the British fauna. The circumstances under which it became established in this country are being investigated. It seems probable that parasites normally associated with *P. subarctica* in Lapland may have become established in this country about the same time. Hymenopterous parasites have been bred from the Forest of Dean material, but have not yet been identified.

Two other species of spruce sawfly provisionally identified as *Pristiphora ambigua* Fallen, and *Pristiphora amphibola* Forster, have been found to be causing widespread damage to Sitka spruce in several localities, including Alice Holt Forest. Both are very small insects about $\frac{1}{6}$ of an inch in length. In each case the eggs are laid singly, on separate developing young shoots, in the spring. The larva of one species causes the attacked young shoot to wilt and curl downwards, ultimately assuming a tassel appearance, often attributed to frost damage. The larva of the other species feeds among the needles at the tip of developing young shoots, generally under cover of the bud scale which remains attached to the tip of the injured shoot. Both types of damage have a pronounced stunting effect on the development of the young trees attacked.

Larvae of at least two other species of spruce sawflies, at present not yet identified, have been found on Sitka and Norway spruce in many localities. It therefore appears that at least seven, or possibly eight, species of sawfly are at present causing damage to Norway spruce and Sitka spruce in Britain. Several of these species are widespread and capable of causing severe damage. A very important point in connection with sawfly attack on spruce is the fact that in cases of severe defoliation by sawflies, the spruce trees are predisposed to successful attack by bark beetles, particularly *Polygraphus*, and of course by *Ips typographus* if the latter species is present. In some recent cases of spruce trees reported as killed by *Polygraphus*, there is evidence that the attack of the bark beetle was preceded by severe defoliation by sawfly larvae. This aspect

of the rapidly developing sawfly menace is undoubtedly of great importance, and in this connection it is considered that the present status of spruce sawflies constitutes one of the most urgent subjects for investigation, and is receiving attention during the sawfly survey this season.

Polygraphus Bark Beetle Infestations

Polygraphus polygraphus L. is a small pitchy black bark beetle about two or three mm. (one tenth of an inch) in length. The wing cases are fairly smooth, and are thickly covered with short scale-like hairs which give the insect a yellowish grey appearance. It can be readily distinguished from other bark beetles by the fact that each eye appears to be divided into two portions. The insect normally breeds in the bark of spruce, but is occasionally found in the bark of pine. It forms a stellate brood system, with galleries radiating from a central pairing chamber. The pairing chamber is generally constructed within the inner bark, consequently the entire brood system is not visible as a complete pattern when the bark is removed.

The species has long been known as a resident breeding species in Britain, under the name *Polygraphus pubescens* Bach. Although a well known pest of spruce in Europe, it first came into prominence in this country in 1936, when it was reported as killing large numbers of mature spruce trees on a private estate in East Anglia. It has since been reported in several localities, and infestations in which spruce trees have been killed have recently been reported from areas extending from Kent to Dorset in the south, also from Norfolk across to North Wales. In some cases investigated, it was found that thinnings left on the ground, or neglected wind blown trees, formed the original source of infestation. In one case the attack and destruction of standing trees was limited to ride-side trees where severe pruning of green branches had taken place. Subsequent investigation has shown that in many cases severe defoliation by sawfly larvae had doubtless predisposed otherwise healthy trees to the attack of the beetle, with fatal results.

Among other cases, *Polygraphus* was recently found to be associated with the infestation of *Pristiphora subarctica* in the Forest of Dean, although the beetle had not previously been recorded from that locality.

Importation of Sawfly Parasites

A consignment of the Chalcid parasite *Dahlbominus* (*Microplectron*) *fuscipennis* Zett., was received from the Dominion Parasite Laboratory, Belleville, Ontario, Canada, through the Commonwealth Bureau of Biological Control.

The parasites were sent in the form of parasitized sawfly cocoons from which about 8,000 adult insects emerged. Several thousand of the parasites were released in the hybrid larch area of Craigvinean, near Dunkeld, Perthshire, where the heavy infestation of the larch sawfly *Anoplonyx duplex* had developed. Some of the parasites were retained at the Forest Research Station for breeding purposes and from these many thousands of parasites were bred. Some of these were liberated at Craigvinean and others in heavily infested larch areas on the Blair Atholl estate.

Owing to lack of cold storage facilities at Alice Holt, the breeding stock died out during the winter of 1949, but another breeding stock was received from Canada in the spring of 1950. From this nucleus stock new colonies have been reared, and several thousand adults have been released at Parkhill in the Forest of Dean where the spruce sawfly, *Pristiphora subarctica*, infestation has developed.

This gregarious Chalcid parasite was first bred in this country at Farnham House Laboratory, Farnham Royal, Bucks, from specimens imported from Europe. It was subsequently sent, along with other species of parasites, to Canada, where millions of the parasites were bred at the Dominion Parasite Laboratory for liberation in the spruce forests of the Gaspé peninsula for the control of the spruce sawfly outbreak. The species readily attacks cocoons of either pine, larch, or spruce sawflies, and is a very prolific species. One sawfly cocoon can support from twenty to forty-five of the parasite larvae, and under laboratory conditions new generations can be produced every three or four weeks.

Export of Sirex Wood-wasp Parasites

Through the Commonwealth Bureau of Biological Control, a request was received for supplies of the Cynipid parasite *Ibalia leucospoides* Hochenw., for liberation in New Zealand to control the *Sirex* wood-wasps in exotic coniferous forest. Collections of these rare parasites have been made, and a substantial shipment sent by air direct to New Zealand. This material has arrived in satisfactory condition, and the work is being continued.

Damage by Short-snouted Weevils in Nurseries

Several cases of damage being caused by Short-snouted weevils in forest nurseries have been recorded. *Barypeithes pellucidus* Boh., a small, pitchy brown, shining weevil about $\frac{1}{6}$ of an inch in length, destroyed a large proportion of the germinating beech seedlings in the seed beds at Haldon Nursery, Devon. *Barypeithes araneiformis* Schr., a similar insect, caused severe damage to *Abies nordmanniana* two-year seedlings in Wareham Nursery, Dorset, and both the above species caused considerable damage at Kennington Nursery, Oxford, by gnawing the bark and destroying the young shoots of poplar cuttings. In other cases these small beetles have caused serious damage to two-year spruce seedlings.

Both the above species of weevils are normally associated with bracken-covered heathland, and flood debris or other decaying vegetation. Heavy dressing of bracken compost was a constant feature in each of the infested nurseries. It therefore seems probable that the liberal use of this type of compost may render nursery soils attractive to these insects, in which case it may be necessary to use a surface dressing of a suitable insecticide. The subject is being investigated.

Aphid and other Pests of Sitka Spruce

Throughout the season the study of aphid and other insect pests of Sitka spruce was continued. Although formerly the Green Spruce Aphis, *Neomyzaphis abietina* Walker, was considered to be the only important insect enemy of Sitka spruce, no fewer than twelve species of insects are now known to cause serious damage to the foliage of the current year. In cases where several of these pests occur in the same area, it seems probable that the combined effects of their attack on young crops may completely turn the scale and prevent satisfactory growth, whereas in the absence of these individually minor pests, the trees might continue to make successful recovery from the effects of *Neomyzaphis* attack. The investigation is being continued and extended.

Consultative and Advisory Work

During the year, ninety-one applications were received for identification of specimens, or for advice on entomological matters. Of these, fifty-three were from members of the Forestry Commission staff, and thirty-eight from private estates, timber merchants, or municipal authorities.

MACHINERY RESEARCH

By R. G. SHAW
Machinery Research Officer

With the rapid development which has taken place in agricultural machinery in the last few years, and the increasing cost of labour, attention has been directed to the mechanisation of many forestry operations. The appointment of a Machinery Research Officer was made in June, and a Headquarters Mechanical Development Committee was formed in September, 1949, to plan and direct his work.

The Committee meets at regular intervals to review the progress made on various projects which it has initiated. Forestry operations which appear to lend themselves to mechanisation are investigated, and where there is reasonable evidence that a machine can be developed to do the work as a lower cost. the project passes to the design stage. Development is carried out by direct contact with commercial firms until the equipment is ready for user trials in the field. A trial sheet is drawn up by the Committee as a guide to the user trials, and to put specific questions on performance, etc., but the users are encouraged to add their own observations on the suitability of the equipment. Certain trials have already commenced at the date of this report, and several projects will reach the trial stage in the months immediately following.

The main lines of development up to the 31st March, 1950, are:—

British Tractors

Investigation into several types of British tractors is being made to find alternatives to the American machines of which the Commission's fleet is almost entirely composed.

In the Size 4 class (30 to 40 drawbar horse-power) the Fowler Marshall V.F. has been working well with the R.L.R. plough. After some early trouble with the front suspension this single-cylinder diesel-engined tractor has proved very reliable and maintenance is simple. Two models are on trial, one in England and one in Wales.

The County tractor which is, in fact, a fully-tracked Fordson Major, is also operating well with the R.L.R. plough; but the trials have not lasted sufficiently long to show whether pulling a plough so heavy as the R.L.R. is not really too much for it as a permanent role. The Roadless Traction Model E which is also a tracked Fordson Major will also be on test shortly. One or both of these tracked Fordson types is likely to be suitable to replace the Caterpillar D.2 and International T.D.6.

A Bristol 20 tractor is on order for trial primarily on lighter work such as extraction, and it is likely that this machine will fill the role hitherto filled by the Clarke Airborne.

Cableways

Cableways are likely to be the only means of extracting timber from some of the more difficult sites, and an investigation into several cableway systems is being made.

It is already clear that for economic operation two conditions must be met:—

(*a*) The time required to transfer the cableway from one site to another should not exceed one day, employing five men.

(*b*) There must be a crop of at least 3,000 cubic feet within reach of the cableway.

Both gravity-operated and power-operated cableways will shortly be on test, the winch of the latter being used for experiments in power skidding with a view to increasing the area served by each cableway.

Chutes

Experiments with chutes as an alternative to cableways are taking place in Scotland, and many of the problems are common to both systems. The time taken to transfer the chute from one site to another is all-important, and for this reason, experiments have been undertaken using light aluminium alloy in sections eight feet long.

Preliminary trials have been encouraging as regards portability and resistance to wear. A complete chute of 600 yards will shortly be on trial.

Simple chutes of corrugated iron are also on test, as they are appreciably cheaper but heavier and less easy to handle.

Peeling

Two portable peeling machines are in the development stage. One machine uses a high speed cutting head under which the log is mechanically fed and revolved. This machine removes a certain amount of wood with the bark, but the finish is very clean. Some difficulty is experienced with crooked logs.

The other machine is simple, light and cheap. In this case flailing chains strike the log, breaking the cambium layer and removing the bark. The feed is by hand. The limiting factor on this machine is the excessive rate of chain wear, and this is being investigated. At present it seems unlikely that any hand-fed machine will be economic on logs above five inches diameter.

Power Saws

Two types of one-man-power saw have been tested in the field. The results suggest that their weight, time required for maintenance and starting, and the need for frequently replenishing the fuel, render them unsuitable for selective felling of trees under nine inches in diameter.

Logging Arches

Various types of arches are in use in the United States but all of them are too large and heavy for use with thinnings.

Two lighter types have been developed, one retaining the arch principle and the other using a jib. The trials are not yet complete, but there appears to be a preference by users for the latter type owing to easier manoeuvreability.

Main Haul

The length of poles now being extracted from many of the Commission's forests makes them quite unsuitable for carriage by standard lorries. Specialised vehicles such as pole wagons and articulated vehicles cannot always be fully employed, and there is a requirement for a dual purpose vehicle.

A two-wheeled trailer has been produced for use with a standard lorry, and experiments will shortly commence. Mechanical loading and unloading devices are also being developed.

Brashing

Two mechanical saws for tree pruning have been demonstrated, but only one shows promise of reaching an output which will achieve a lower cost per acre than by hand methods. A number of these saws are being operated on contract by the inventor, and negotiations are in hand to obtain one machine for our own trial to establish a direct comparison with the cost of hand brashing.

LIBRARY AND DOCUMENTATION WORK

By G. D. KITCHINGMAN
Documentation Officer

Books Section

The number of books in the library on 31st March, 1950, was 1,320. 381 books were loaned during the year from the Lending Library. This figure does not include many borrowed for less than a day, which are not entered in the loan register.

Periodicals Section

The number of bound volumes in this section increased from 723 to 791. Many more could be bound if only we could get hold of the odd numbers missing here and there.

Information Files

Work was continued on building up these files, in which a great deal of loose material can be conveniently stored, and found again if properly indexed. Nothing is filed until it has been fully catalogued in the card index. There are now eleven cabinet drawers of classified information files.

Cataloguing work

All books and periodicals have now been reclassified under the International Decimal Classification, and we have now a complete catalogue of cards. Work has begun on the preparation of a catalogue.

Documentation

Documentation work has been severely handicapped by the changes that have occurred in the International Decimal Classification system which is adopted in the library. Many thousands of index cards have had to be re-classified. It is expected that a reasonable degree of finality in the system will be achieved in autumn 1950 when the International Union of Forest Research Organisations passes judgement on the revision of the classification which has been worked out by its bibliographical committee.

The amount of documentation work done, i.e., referencing for the making of bibliographies and for the answering of enquiries regarding published literature and other information on specific subjects, is limited by the staff available for reading and referencing. This is work which can only be done properly by someone possessing the requisite technical knowledge, and the need for further assistance in this is acutely felt. There is scarcely any limit to the amount of useful referencing work that *could* be done if suitable men could be found to work temporarily on specific subjects. A certain amount of summarising (in English) of articles in foreign languages has been done by visiting students from abroad, whose help has been very welcome.

The number of cards in the card index is now about 18,000 representing perhaps 5,500 references. And the more cards we have the easier it will be to find literature asked for.

Library Quarterly

Four numbers of the Quarterly were circulated during the year. Each issue contained (1) An annotated list of new books added to the lending section of the library, and (2) A library record intended for the use of forest libraries

generally. Of the four Records issued, two contained a list of periodicals held in the library, and two were bibliographies—one for *Pinus laricio* (Syn. *Pinus nigra* var. *calabrica*) Corsican pine and the other for"Sand-dune afforestation". We have been encouraged to continue this little serial by the thought that it may be helpful to those who wish to keep up-to-date with their professional work; and that it may further co-operation between forest libraries of the world, especially in the preparation and exchange of bibliographies.

PHOTOGRAPHIC SECTION

By I. A. ANDERSON
Photographer

Although by the 31st March, 1950, the Photographic Section had officially been in existence for nine months, it has really functioned for a considerably shorter period, owing to the fact that the first months were occupied in organization and the acquisition of equipment. The Section started at a very serious disadvantage in that there was an accumulation of over two thousand negatives at Alice Holt which required classification and printing.

The Central Photographic Collection is being organised and over 2,500 prints have been made, nearly 900 photographs taken and nearly 1,500 developed. In addition, a great deal of experimental work has been carried out to find the most suitable materials for forest photography. This work is now complete, and standardisation of films and developers is under way. A small amount of colour work has also been done and, by the time this appears in print, it will be possible to produce colour prints within the section. The production of colour prints, being an expensive and time consuming process, must at present be limited to exhibition work, though colour transparencies may of course be used for reproduction in publications.

PUBLICATIONS

The following papers were published by members of the Research staff during the year:—

EDWARDS, M. V.	Soil Sterilisation in the Royal Botanic Garden by the Forestry Commission Research Branch. *Journal of the Edinburgh Royal Botanic Garden Guild*, Vol. 5, Pt. 2, pp. 18-20, 2 plates. 1947-48.
GRAY, W. G.	*The Raising of Aspen from Seed.* Forestry Commission Forest Record, No. 2. (1949)
GUILLEBAUD, W. H. and HUMMEL, F. C.	A note on the Movement of Tree Classes. *Forestry* XXIII. No. 1, pp. 1-14. (1949)
HUMMEL, F. C.	The Methods Employed in the National Forest Survey of Great Britain, 1947-1949. The *Proceedings of the Third World Forestry Congress*, No. 1, pp. 39-52.
HUMMEL, F. C.	*Revised Yield Tables for Japanese larch in Great Britain.* Forestry Commission Forest Record No. 1. (1949)
HUMMEL, F. C. and BRETT, I.	A Simple Method of Estimating Volume Increment in Stands of Young Conifers. *Empire Forestry Review.* Vol. 29, No. 1, pp. 58-59. (1950)
MACDONALD, JAMES and HENDERSON, F. Y.	Research in Forestry and Forest Products in the United Kingdom. *Unasylva*, Vol. IV, No. 1. (1950)
MACDONALD, J. A. B.	Conifers on the West Coast of Scotland. *Arboretum Bulletin* (Washington, U.S.A.), Vol. 13, No. 2, pp. 14, 15, 30. (1950)
PEACE, T. R. and GILMOUR, J. S. L.	The Effect of Picking on the Flowering of Bluebell, Scilla non-scripta. *New Phytologist*, Vol. 48, No. 1, pp. 115-7. (1949)
PEACE, T. R. and HANSON, H. S.	*The Control of Forest Diseases and Insect Pests in Great Britain.* Paper for the United Nations Scientific Conference on the Conservation and Utilisation of Resources. (1949)
PEACE, T. R. and WALLER, S.	Death of Sycamore Trees associated with an unidentified fungus. *Nature*—164, 4163, p. 275. (1949)
WOOD, R. F.	The Rehabilitation of Devastated and Derelict Woodlands. *Quarterly Journal of Forestry*, Vol. 44, No. 1, pp. 5-10. (1950)

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 1949 EXPERIMENTS

By DR. E. M. CROWTHER
Rothamsted Experimental Station

1. Introduction

The general purposes of the investigations, and the pattern of the co-operation between the Research Branch of the Forestry Commission and the Chemistry Department of Rothamsted Experimental Station were described under the heading "Summary Report on 1948 Experiments" in the *Report on Forest Research for* 1949 (page 60). In 1949, large series of seedbed experiments were continued or new ones laid down at the following nurseries:—

1. Kennington, near Oxford—old established nursery.
2. Kennington Extension, near Oxford—taken over from arable land in 1945.
3. Bagley Wood, Oxford—forest clearing.
4. Wytham, Oxford—forest clearing.
5. Sugar Hill, Wareham, Dorset—heathland.
6. Ringwood, Hants.—old established nursery.

Smaller series of experiments were also continued at the following nurseries:—

7. Nagshead, Forest of Dean—old established nursery.
8. Tair Onen, Glamorgan—old established nursery.
9. Harwood Dale, Allerston Forest, Yorks.—heathland nursery (old).
10. Wykeham Moor, Allerston, Yorks.—Forest ride on heathland.
11. Wykeham, Allerston, Yorks.—old established nursery.
12. Widehaugh, Northumberland—old established nursery.
13. Longtown, Cumberland—new nursery on aerodrome site.

Transplant extension or manuring experiments were made at several of the above nurseries and also in Conservancy nurseries at Reasty Top, Allerston, and Rosedale Banks, Yorkshire. In addition a new series of experiments was started in 1949 in an old established nursery at Ampthill, Beds. This centre

was selected in order that microbiologists and chemists at Cambridge and Rothamsted could collect soil samples periodically for detailed laboratory work with a minimum delay.

From 1945 to 1948 most of the seedbed experiments had been on square-yard plots split into halves for Sitka spruce and Scots pine. To simplify the field work, assessments and computations, it was decided that from 1949 onwards the plots were to be sown only with Sitka spruce, which had proved to be by far the more delicate and sensitive test crop.

Forest planting experiments to test the performance of seedlings and transplants from nursery experiments, and also the effect of fertilizers applied near the time of planting were laid out at:—

Broxa, Allerston Forest, Yorkshire....	*Calluna* (Heather) moorland
Mason's Bank, Kerry Forest, Shropshire	*Calluna* (Heather) moorland
St. Gwynno Forest, Glamorgan	*Molinia* grassland
King's Forest, Suffolk	Grass heath.

As little growth is expected in the first season after planting, the present report deals only with results from forest plantings in the spring of 1948, at Broxa, Dartmoor, St. Gwynno Forest, King's Forest, and Decoy Heath, Wareham Forest.

2. The 1949 Season

For the third consecutive season seedling growth was poor. The prolonged drought of 1949 had a much more severe effect than that of 1947. In 1949, the soil was quite unusually dry when the seedbeds were being prepared in March, and it is probable that at some nurseries standard methods of incorporating manures, consolidating the soil, and covering the seeds were inappropriate for these very dry conditions. Since 1947, all seedbeds in these investigations have been without slatted shades, and it is likely that in 1949 full exposure aggravated losses of young seedlings, especially early in the summer. The intense drought greatly magnified the effects of minor soil irregularities and disturbances by nearby hedges, grass leys or paths. Even where most of the plots in an experiment carried good stands, a number of abnormal plots often spoilt the results.

3. Fertilizers and Bulky Manures

Early in the summer, plots with composts or other bulky manures had markedly poorer stands than those with fertilizers only. As the season advanced the plant numbers evened out, and by the end of the season plant numbers on the fertilizer plots had fallen nearly as low as those on the compost plots. The numbers were often lowest on plots with bulky materials such as chaffed bracken, chaffed straw and straw composts. It would appear that the bulky manures left the soil too open and allowed it to dry out too rapidly early in the season. There may, however, have been other factors at work, for fresh hop waste has given low total plant numbers in experiments at several nurseries over several seasons. This loss of plants has introduced ambiguities into statements of experimental results in terms of mean heights. Although for most of our experiments there has been a satisfactory correlation between mean heights and numbers of usable plants, plots with fresh hop waste have often fallen out of line, with high mean heights for the numbers of usable plants. The mean heights were high because the small plants had died. It may be interpolated here that some Conservancy heathland nurseries on which fresh hop waste had been used in 1949 also had fair stands of good plants with an abnormally low proportion of small plants. Sometimes composts and fresh

hop waste may produce beds with an attractively even stand because early deaths reduce competition later in the season. In most nurseries the differences in growth with composts and fertilizers were relatively small and irregular in 1949.

As in many agricultural experiments of 1949, nitrogen fertilizers gave little benefit to seedlings. Available nitrogen in the soil tends to be high in dry seasons, and added nitrogen, by increasing the ratio of tops to roots, aggravates the effects of drought. Superphosphate improved the growth of Sitka spruce seedlings at most nurseries in 1949. Potassium fertilizers improved growth at Bagley Wood and Longtown nurseries. There was also an improvement of Corsican pine seedlings by potassium fertilizer at Sugar Hill Nursery, Wareham, in an experiment testing several species on the same plots.

In experiments at the old Kennington nursery and at Ringwood, testing additions of small amounts of iron, manganese, zinc, copper and magnesium salts, and borax, there were no responses in Sitka spruce.

4. Soil Acidification

In several experiments started in the winter of 1946-7 to test the effects of acidifying soils of neutral or slightly basic reaction, additional acidification was carried out in the winter of 1948-9 by means of heavy dressings of ammonium sulphate or sulphur, with the object of obtaining wider ranges of soil reaction. The low rainfall throughout the early months of 1949 allowed the soluble salts inevitably produced by these treatments to remain in the surface soil, and in many experiments the seedlings suffered severe damage on the re-acidified plots. In several experiments with damaging acidification treatments in 1949, the plots carried good seedlings early in the summer of 1950. It has, of course, been realised since the inception of this work that acidification treatments would not be given in practice shortly ahead of sowing sensitive seeds, but the test plots have generally been cropped in the first season to assess the immediate danger. In 1949 a few experiments were laid down with acidification treatments on land left fallow in preparation for cropping in 1950. At the time of writing this report (July, 1950) acidified plots at Kennington and Ampthill are carrying more and better seedlings than the associated untreated plots. At Nagshead nursery there were benefits in 1949 from three annual dressings of sulphur, but the mean heights throughout the experiment were very poor.

5. pH Range

The series of plots laid down at Kennington Extension and Wareham nurseries in 1947-8 to test the effects of a wide range of soil reactions, artificially induced, on a large number of species as seedlings and transplants, gave much less striking results in 1949 than in 1948. The extreme contrast between ash, which failed on the acid soils, and birch, which grew poorly on the neutral soils, stood out sharply; but most of the conifers grew fairly well at all except the most extreme pH values. *Pinus halepensis* (Aleppo pine) turned yellow and grew very badly over most of the acid range at Wareham.

6. Formalin

Formalin again gave excellent results in most of the experiments in which it was tested on neutral or moderately acid soils. It had no effect on very acid soils at Wareham and Bagley Wood. Several experiments were made on the residual effects of earlier applications of formalin, and on possible modifications of formalin effects by other treatments. In one experiment, on a moderately acid soil at Kennington Extension, the application of formalin in 1949 reduced growth, whereas in the same experiment residues from formalin applied in 1948 increased growth, except on plots which also received sulphur in 1949.

In one Old Kennington experiment the incorporation of chaffed straw in the winter of 1948-49 offset the residual benefit from formalin applied early in 1948, though the residual effect of formalin was well shown on plots without subsequent additions of chaffed straw. The residual benefits from formalin and steam, in the crop sown more than twelve months after treating the soil, were clearly shown in experiments at Ringwood nursery.

In several experiments solid paraformaldehyde gave improvements approaching those from formalin solutions.

7. Steam and Formalin

In a new series of experiments set up in 1949 at Ampthill Nursery, Bedfordshire, primarily for detailed chemical and microbiological studies on the mechanisms of steam and formalin treatments, the benefits on Sitka seedlings were dramatically successful. The results may be summarised briefly as follows:

	Mean height inches	*Total plants per sq. yd.*	*Plants over 1.5 inches per sq. yd.*
Untreated	1.06	798	114
Formalin	2.07	756	540
Steam	2.47	792	630
Steam and Formalin	2.58	738	630

The out-turn of usable plants was increased about five-fold. In practice the treated plots would have been cleared for transplanting, and the untreated ones would have been left for a second year's growth of the seedlings.

One of the most interesting features of these experiments was the sharpness—to a few inches—of the boundary lines between treated and untreated plots. In sample plants washed out with a minimum of disturbance across a boundary, the treated plots carried strong plants with thick roots a foot long, whilst the untreated plots had thin spindly plants with roots only a few inches long. Still more vivid were the results of a small supplementary experiment in which formalin was applied in two shallow narrow drills eighteen inches apart. Close to the bands the plants were as good as those on plots uniformly treated with formalin, whilst midway between the drills the plants were as poor as on untreated plots.

In the early summer the soils of the steam and formalin plots had high ammonia contents, and gave large quantities of carbon dioxide on incubation in the laboratory; but in autumn the steam and formalin plots gave less carbon dioxide than the untreated plots. All plots had high nitrate contents during the very dry autumn; additions of nitrochalk in July had no effect on the growth of seedlings.

The Rothamsted Microbiology Department made detailed studies on the qualitative and quantitative changes in the microflora. They will continue the work through 1950 to determine the duration of the drastic changes brought about by steam and formalin.

8. Seed Covers

In second-year experiments on seed covers at Wareham and Ringwood, the best plants were from plots with Leighton Buzzard 2L sand, and the worst with limestone chips. Calcareous covers gave lower plant numbers than non-calcareous covers. In experiments during the past few seasons, Leighton Buzzard sand has been blown off the plots in several nurseries, and it has therefore been decided to use instead a coarser material—a quartz waste from the St. Austell china-clay workings.

9. **Watering**

As would have been expected in a drought year, watering seedbeds increased heights and plant numbers.

10. **Transplant Experiments**

Transplants made poor growth in the 1949 season, and in most extension experiments the relative height differences in the original seedlings were maintained at the end of the season. In a few extension experiments at Old Kennington and Kennington Extension the gains from certain seedbed treatments (acidification or superphosphate) stood out more clearly than in the original seedlings.

Two small sets of observation plots were laid down at Sugar Hill Nursery, Wareham, to compare, as transplants in 1949, seedlings raised in 1948 with compost in the old part of the nursery on repeatedly composted soil, and those raised with fertilizers in the new part of the nursery on land which had never received compost. One of the two transplant sites was on repeatedly composted soil in the old part of the nursery, and the other on land which had never received compost in the new part of the nursery. The mean heights and shoot growths were:—

	Height, inches	*Shoot, inches*
In old nursery—		
ex old nursery	8.9	6.9
ex new nursery....	9.8	7.2
In new nursery		
ex old nursery	8.1	6.2
ex new nursery....	9.4	6.8

Seedlings raised with fertilizers in the new part of the nursery grew slightly better as transplants than those raised on the repeatedly composted seedbeds. The transplants in the old composted nursery were bigger than those on the poor soil in the new nursery.

The results of these observation plots on seedlings raised in 1948 agree with those of forest observation plots planted with seedlings raised in 1947 (see para. 14 below), in showing that plants from the old composted nursery had no advantage over those raised with fertilizers in the new section of the nursery.

11. **Transplant Manuring Experiments**

In most manurial experiments on transplants responses were small. In a second-year experiment at Reasty Top, Allerston Forest, North Yorkshire Moors, on a site cleared from *Calluna*, superphosphate and repeated applications of nitrogen fertilizers gave one-plus-one Sitka spruces 6.4 inches high, as compared with 4.8 inches without these fertilizers.

12. **Rotation Experiments**

Rotation experiments were started in 1948 at Wareham and at Kennington Extension, to compare seedbeds on which Sitka spruce was grown continuously with those with either fallow or various cover crops every third year. The first test crop of Sitka spruce was taken in 1949, and at both centres the best plots were the ones which had been fallowed or had carried conifer seedlings in 1948. At Kennington Extension, Sitka spruce seedlings after good crops of white clover were much poorer than those after lupins, rye or perennial ryegrass. At both centres the test crops of 1949 were better on plots with compost than on those with fertilizers. The failure of organic residues from good resting

crops to improve Sitka spruce, indicates the need for caution in applying ordinary agricultural principles of crop rotation to forest nurseries. Results over many more seasons will be needed before reliable conclusions can be drawn from these experiments.

In another Kennington Extension experiment there were benefits in the 1949 Sitka seedlings from the residues of a grass ley grown and dug in in 1947.

It was decided to prepare sites for new long-term experiments on crop rotations and manuring at Wareham and at Kennington, to be sown in 1951.

13. Forest Extension Experiments

The 1948 extension experiments, testing the behaviour of seedlings and transplants from experimental nursery plots when planted out in the forest, were made without manuring in the forest. Differences due to nursery treatments were relatively small, apart from high losses in a few cases where particularly small seedlings were taken from plots deliberately limed to aggravate suspected troubles. The percentage of deaths by the end of 1949, averaged over all plots in each forest, are shown in Table 18 below.

PERCENTAGE OF DEATHS, BY LATE 1949, OF TREES PLANTED EARLY IN 1948

Table 18

Forest	1+0 Seedlings		1+1 Transplants	
	Sitka spruce	Scots pine	Sitka spruce	Scots pine
Broxa, Allerston	2%	8%	0	1%
Dartmoor	29%	12%	3%	1%
St. Gwynno	8%	—	5%	—
King's	—	9%	—	1%

The unusually high proportion of deaths of Sitka seedlings in Dartmoor can be ascribed to planting small plants a year after ploughing on a site which, being near farm buildings, rapidly developed a rank growth of grass. In manuring experiments planted at the same time a little further from the farm, the percentages of deaths were 13% and 17% for Sitka spruce and Scots pine seedlings respectively. At the other forests survival of seedlings and transplants was satisfactory.

14. Planting of Seedlings and Transplants from the Old and New Nurseries at Sugar Hill, Wareham

It has often been stated that seedlings and transplants raised with composts survive and grow better in the forest than those raised without compost, but it is difficult to see how this generalisation can have been substantiated. Conifers grow very poorly on unmanured heathland, and it would not be surprising if such plants behaved poorly in forests by comparison with those liberally manured with composts. Until the present series of investigations was commenced, no seedlings had been raised on heathland soils with adequate amounts of nutrients supplied by fertilizers, and it had therefore been impossible to compare the subsequent performance of plants of similar size but differing only in the circumstance that one batch had derived its nutrients from compost, and the other from inorganic sources.

Following the successful growth of seedlings with fertilizers at Sugar Hill Nursery, Wareham, on land which had never received compost, and their excellent performance in transplant experiments and at several Conservancy

nurseries, it was suggested that the series of forest planting experiments should be supplemented by a set in which plants raised with fertilizers on the new sections of the Sugar Hill Nursery should be compared in forest planting experiments with those grown on repeatedly composted land in the old sections of the nursery. This comparison could not of course be rigid, because there might well be inherent soil differences between the two sites, and variations in cultural details; but many years would have to elapse before it would be possible to test the effects of long-continued compost treatments in critical experiments. It was considered that a preliminary test might at least show whether there was any striking difference in performance, such as appears to have been commonly assumed.

4×4 Latin squares, with seedlings and transplants from the old and new sections of the nursery, were laid out at five forests, three with alternating pairs of Sitka spruce and Scots pine, and two with a single species. The plants from the new sections were from land which had not previously carried conifer seedlings or transplants, and which was manured only with fertilizers. The plants from the old nursery were from land which had received compost annually for several years. In the forest, half of the rows in each plot received an inorganic fertilizer supplying nitrogen and phosphate but no potassium.

At the time of planting, early in 1948, the Sitka spruce seedlings and transplants from the old nursery were appreciably larger than those from the new nursery. The Scots pine transplants from the new nursery were larger than those from the old. Height assessments at the end of 1949, i.e., after two seasons' growth in the forests, are given below in Tables 19 and 20.

MEAN HEIGHT OF SITKA SPRUCE IN INCHES, IN FOREST, AFTER TWO SEASONS' GROWTH

Table 19

	(At planting, 1948)	Decoy Heath, Wareham	Broxa, Allerston	Dartmoor	St. Gwynno	Mean percentage deaths
Planted in 1948 as:						
1+1 ex Old nursery	(7.2)	13.8	17.8	13.3	19.7	1%
1+1 ex New „	(5.9)	10.8	14.1	12.2	18.0	6%
1+0 ex Old „	(2.4)	6.7	13.7	6.4	14.0	7%
1+0 ex New „	(1.8)	8.7	15.3	8.9	16.2	7%
Without fertilizers	—	7.4	13.2	8.5	16.8	4%
With fertilizers	—	12.6	17.1	11.9	17.2	7%

MEAN HEIGHT OF SCOTS PINE IN INCHES, IN FOREST, AFTER TWO SEASONS' GROWTH

Table 20

	(At planting, 1948)	Decoy Heath, Wareham	Broxa, Allerston	Dartmoor	King's	Mean percentage deaths
Planted in 1948 as:						
1+1 ex Old nursery	(2.8)	13.0	11.7	11.6	11.1	1%
1+1 ex New „	(4.1)	14.6	13.3	13.6	12.3	2%
1+0 ex Old „	(2.2)	8.8	8.5	8.6	8.4	14%
1+0 ex New „	(2.3)	9.2	10.7	10.0	8.1	6%
Without fertilizers	—	9.4	10.3	10.6	9.9	4%
With fertilizers	—	13.4	11.8	11.3	10.0	7%

The Sitka spruce transplants from the old nursery maintained their superiority over those from the new nursery, but the Sitka spruce seedlings from the old nursery fell behind those from the new nursery in each forest. The Scots pine from the new nursery were taller than those from the old nursery in seven of the eight tests. Deaths in the forest were particularly high in Scots pine seedlings from the old composted nursery.

The results of this trial agree with those from many small plot experiments in the new section of Sugar Hill Nursery, and in several other nurseries, in showing that the early performance in the forest is much the same whether the plant obtained its nutrient supply from compost or from fertilizers. The experiments will, of course, be continued.

The table also brings out marked differences between the various forests in the heights of the plants and their responses to fertilizers. Sitka spruce responded well to fertilizers at Decoy Heath and Broxa, both *Calluna* (heather) sites; Scots pine responded well only at Decoy Heath. Fertilizers had little effect on growth on the very grassy sites at St. Gwynno and King's Forests. The percentage of deaths was increased by fertilizers applied in the forest.

15. Fertilizer Responses in Forests

Other experiments in the same forests, planted in 1948 and assessed in autumn, 1949, tested the effects of nitrogen, phosphate and potassium fertilizers viz., "nitrochalk", superphosphate and potassium chloride: results are shown in Table 21 below.

MEAN HEIGHT IN INCHES OF SITKA SPRUCE AND SCOTS PINE, TWO YEARS AFTER PLANTING, WITH VARIOUS MANURIAL TREATMENTS

Table 21

	Sitka spruce				Scots pine			
	Decoy Heath, Wareham	Broxa, Allerston	Dartmoor	St. Gwynno	Decoy Heath, Wareham	Broxa, Allerston	Dartmoor	King's
	Planted as 1+1 transplants							
Mean	14.0	15.0	8.5	14.1	15.1	12.4	11.4	11.2
Effect of:								
N.	0.4	3.0	0.3	0.6	—0.4	1.3	—1.1	—0.7
P.	9.4	2.9	1.6	1.5	8.4	0.6	.04	—0.2
K.	2.0	0.5	0.2	0.2	0.2	0.3	0.4	1.5
	Planted as 1+0 seedlings							
Mean	10.5	16.5	7.2	12.6	12.3	9.6	7.8	8.6
Effect of:								
N.	—2.0	1.0	—0.3	—2.0	—2.8	0.1	—1.8	—0.9
P.	9.8	5.5	2.7	2.8	7.3	0.3	0.9	—0.4
K.	0.0	1.2	0.0	0.2	0.9	0.5	0.2	2.0

N=Nitrogen. P=Phosphorus. K=Potassium

Sitka spruce planted as one-year seedlings or one-plus-one transplants responded well to phosphate at all four forests, the increases in height being particularly great in the Decoy Heath area. Nitrogen increased height significantly only on Sitka transplants at Broxa. Potassium chloride gave moderate height increases on Sitka spruce transplants at Decoy Heath, and on both

seedlings and transplants of Scots pine at King's Forest. It will be noted that nitrogen and phosphate fertilizers, which were the only ones tested in a number of the other experiments, both reduced the heights of Scots pine at King's Forest.

The early results of these experiments were much influenced by the severe drought of 1949, and by competition with grasses on the Dartmoor, St. Gwynno and King's Forest sites. Observations early in the summer of 1950 indicate that important changes may take place during the next few years. The Decoy Heath plants grew very well on manured plots in 1949 in spite of the drought, but by July, 1950, they were showing all the signs of going into check. At King's Forest the benefit from potassium showed much more clearly in July, 1950, than is indicated in the 1949 assessments.

16. Forms of Fertilizers and Methods of Application for Forest Manuring

Many experiments have been made to compare alternative forms of fertilizers, and methods of application to newly planted trees. Superphosphate has often proved superior and never inferior to the other forms of phosphate fertilizer tested. No satisfactory form of nitrogen fertilizer has yet been found, and several new materials are under test. Several early experiments were made with formalized casein, a material known to act slowly, but the interpretation of the results is complicated by the high availability of the small proportion of phosphate present. Soluble forms, e.g., ammonium sulphate and ammonium nitrate, may be expected to act only in the first season or so, and to stimulate grass and other weeds unduly. There is some evidence that on a potassium-deficient site, such as King's Forest, nitrogen and phosphate fertilizers may retard growth, perhaps by aggravating the effects of potassium deficiency and by increasing weed competition.

The 1948 plantings were the first in this series of investigations to test inorganic agricultural compound fertilizers. With the lack of previous experience on using such materials in the forest, it was decided to compare applications broadcast around the young plant with localised placement in notches cut with a spade about six inches on either side of the young tree. In the first two seasons there were negligible differences between the results. The broadcast application is, of course, far simpler and quicker. More recently it has been found convenient to apply the broadcast fertilizers in bands or patches on two sides of the young tree, and at least six inches away from it. This leaves a considerable area without fertilizers around the young tree, so that, in the event of any temporary check or damage to roots by fertilizer salts under unfavourable seasonal conditions, root development may proceed more normally in the patches of untreated soil. In 1949 and 1950 plantings, fertilizers were tested in the form of one-ounce pellets. The soluble nutrients present diffused out of the core of gypsum within a few months, and it does not at present appear that the extra cost of pelleting would be justified. In both years, extension experiments were set out in manured and unmanured blocks to provide larger units for testing the effects of manuring on the time of canopy formation.

17. Pot Experiments

The 1949 experiments were devoted mainly to comparing three kinds and sizes of pots for experiments on Sitka seedlings. The technique developed was successful in demonstrating the improvements by steam, formalin and acid in soils from old established nurseries. It is being used in 1950 to test a number of soil fungicides in an attempt to analyse some of the factors involved in "partial sterilisation".

MICROBIOLOGICAL INVESTIGATIONS AND WORK ON COMPOSTS

By DR. IDA LEVISOHN
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Organic Composts

At Bedford College, experimental composts were prepared from a number of relatively easily available basic materials; i.e., bracken, heather, sawdust, using the following activators: hopwaste, coffee-grounds, and a proprietary compound. In the rather small heaps at Bedford College, the two latter activators have not yielded satisfactory results judged from the appearance of the final product. Another proprietary compound as a converter of sawdust is also under experimental observation.

Pot-cultures

The routine check on field experiments concerning new composts and additional tree species was carried out in the Möller shelter-house.

A pot-culture experiment was set up to study the effect on root development of Scots pine of drainage water from soils carrying mycorrhizal seedlings, and from untreated and "sterilized" soils which do not carry plants. The experiment is a first step of an enquiry into certain root reactions taking place in soils in the absence of fungal root associates. The test seedlings raised under conditions that keep them free from root infection have been watered with sterile (Berkefeld-filtered) drainage water from the various sets of soil mentioned. During the growing season, the effect on root development (colour, growth, and in particular branching) will be examined.

Other cultures cover a series of Sitka spruce seedlings raised under relatively similar conditions but having received differential treatment as regards mycorrhizal infection. One series has been kept uninfected, while the other series had been inoculated with sporophore and pure culture mycelium of *Rhizopogon luteolus*. Both series are intended to be planted out in the autumn on a prepared "poor" site. The experiment will be a test of the behaviour in virgin soil at Wareham Forest, Dorset, of mycorrhizal plants, as compared with non-mycorrhizal plants of relatively similar origin.

A number of pot-experiments were designed to analyse further the phenomenon of haustorial infection so frequently encountered in certain species from run-down nurseries. So far, the results have confirmed the view that the organisms responsible for such infection vary considerably as regards their virulence and that, at least in the case of certain haustorial mycelia, the soil pH is not a limiting factor to their activity in the cortical cells of the host plant.

Laboratory Research

Research has been focussed on the study of root mycelia (mycorrhizal and pseudo-mycorrhizal) as compared with "trivial" soil fungi (i.e.. *Pullularia*, *Chaetomium* and *Alternaria* spp.). Differential behaviour of these physiological groups of mycelia was recorded in culture media with various cellulosic and other plant tissue materials. The pseudo-mycorrhizal mycelia tested so far have produced in these dead materials characteristic structural bodies identical with those formed in the live roots under natural conditions. Cultures were set up to analyse the conditions under which such structures are produced.

Sugar Hill Nursery

At Sugar Hill Nursery, Wareham Forest, Dorset, the routine cultural procedures were applied as usual, and a number of additional tree species were raised successfully.

During the last few years, spread of fertility within the nursery has affected the control section. Gradually the controls have shown marked improvement in growth and also (simultaneously) in respect to mycorrhizal infection. In order to provide adequate "normal" controls, 1949 control sowings were extended to virgin soil outside the nursery.

Experimental trials of shoddy composts gave good results in transplant lines, while treatment of seedbeds with shoddy composts produced poor crops. Preparation of shoddy composts is abandoned, as shoddy used as a basic or starter material is not an economic proposition.

THE EFFECT OF PARTIAL STERILISATION ON THE OCCURRENCE OF FUNGI IN THE SOIL

By J. H. WARCUP

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1st Report—(13th June, 1949)

An examination of the alteration of the fungus flora of forest nursery beds after partial sterilisation with steam or formalin was undertaken on plots at the Old Ampthill Nursery, Bedfordshire. Six plots, fifteen feet by sixteen feet, were set up; two were given steam treatment, two were given formalin, and two were kept as controls. The soil treatments were carried out by members of the Forestry Commission staff during the second week of March, 1949. The plots were subsequently sown with Sitka spruce in the first week of April, 1949. For the mycological investigations soil samples were collected just before the treatments, at the time of treatments (within forty-eight hours), and since then at approximately three-week intervals. These collections are being continued.

Methods

Soil samples have been taken from each plot. Each sample was obtained by exposing a soil profile and collecting small samples of soil at one or two inch intervals down the profile. The plots were sampled to a depth of twenty-two inches, except for two plots where the C horizon of Lower Greensand occurred at fourteen inches. Soil plates for the isolation and study of fungi were prepared from the samples at each depth, and the occurrence of the fungi plotted against the profile.

Results

(1) GENERAL

Over 100 species of fungi have been obtained from the six plots and about one-third to one-half are of constant occurrence. Species of *Pythium*, *Mortierella Mucor*, *Aspergillus*, *Chaetomium*, *Gliocladium*, *Fusarium*, *Penicillium*, and *Trichoderma* are common. In a profile from a control plot most of the fungi occur throughout the worked layer of the soil, from surface to ten inches deep.

Below ten inches there are far fewer species of fungi and these are rather different from those which are common above. Species of *Penicillium* are common in this lower region. This division of the flora is closely correlated with the two divisions in the profile of the Ampthill Nursery soil. From surface to ten inches there is a grey sand layer; from ten to twenty-two inches the soil is a looser orange coloured sand.

(2) EFFECT OF PARTIAL STEAM STERILISATION

Samples taken immediately after steaming showed that almost all the fungi (and bacteria) had been killed throughout the profile to a depth of about twelve inches. Most of the "bottom" flora was still present.

Samples at three weeks: Plates from the upper fourteen inches still almost sterile. A few colonies of an *Aspergillus* and two species of *Penicillium* occurred near the surface.

Samples at six weeks: A flora consisting mainly of species of *Mortierella* and *Trichoderma* has returned near the surface (surface to four inches). Plates from six to twelve inches still largely sterile.

Samples at nine weeks: As at six weeks, with a few more fungi present and the *Mortierella* sp. and *Trichoderma* deeper in the soil.

(3) EFFECT OF FORMALIN TREATMENT

Samples taken two days after treatment showed that the formalin had not penetrated very far, one and a half and four inches respectively. Plates from those regions remained sterile; other depths had a normal flora.

Samples at three weeks: The formalin appeared to be still travelling downwards, as the isolation plates remained sterile to two-and-a-half and five inches respectively.

Samples at six weeks: Plates sterile to four and six inches.

Samples at nine weeks: Fungal flora, mainly *Trichoderma viride*, returning to the surface areas of the soil.

At this time (mid-June), no appreciable difference in growth of the seedlings in the various plots could be detected.

Second Report—(26th August, 1949)

Two further series of soil samples were collected from the experimental plots at the Old Ampthill Nursery, Bedfordshire. These samples show few changes in the fungal floras of the plots since the last examination in June. These collections are continuing.

Steam-treated Plots

There is now a partial fungal flora, by numbers and species, throughout the whole soil profile. The most common fungi in this partial flora are species of *Mortierella* and several unidentified pycnidial fungi. Several other species show a scattered distribution throughout the profile. However the flora is greatly reduced compared with that of the control plots, and some small portions of the profile are still devoid of fungi.

Formalin-treated Plots

The surface zone, from surface to five to eight inches deep, which was affected by the formalin treatment, now shows a partial flora consisting mainly of *Trichoderma viride*. Occasionally Actinomycetes or bacteria appear to be locally common in this zone.

Growth of Sitka Spruce Seedlings

There are now considerable differences in the growth of the seedlings on the variously treated plots. The seedlings in both the formalin and steam

treated plots are showing better growth than those in the control plots, but at the moment it is difficult to decide which treatment is supporting the better growth of the Sitka spruce. Within three of the plots, seedlings in the three seed-beds of each plot also show some differences in growth although receiving the same treatment; these differences are presumably due to variations in the soil.

Third Report—(September, 1950)

Experimental Results for 1949

Soil samples were collected from the experimental plots at the Old Ampthill Nursery, Bedfordshire, until November, 1949, eight months after the partial sterilization treatments. During that period ten soil samples were collected from each plot and the results of the mycological examinations of these samples are summarised below.

Steam-treated Plots

The treatment was found to have penetrated the soil and killed most of the fungi to an average depth of sixteen inches. Fungal recolonization was evident six weeks after the treatment, and appeared to spread downwards from the surface layers of soil. By November there was a partial fungal flora, by numbers and species, throughout the whole of the treated zone. The most common species in this partial flora were *Mortierella*, *Coniothyrium* and several unidentified species.

Formalin-treated Plots

Formalin penetrated the soil and killed the fungi to a depth of four-and-a-half inches on the average. This treated zone was mainly recolonized by *Trichoderma viride*, and even in November this fungus was still dominant and few other species were recorded.

Growth of Sitka Spruce on the Experimental Plots

Soil sterilisation either by steam or formalin significantly increased the total number of seedlings and appreciably increased the mean height of the seedlings. There was no significant difference between the steam and formalin treatments in numbers, but steam sterilisation gave considerably taller seedlings, the difference being possibly significant. Considerable damping-off was observed on the control plots but not on the treated plots. Table 22 shows the number of seedlings per square yard and the mean height of the seedlings.

DENSITY AND HEIGHT OF FIRST YEAR SITKA SPRUCE SEEDLINGS GROWN AFTER STERILISATION OF THE SOIL

Table 22

Treatment	No. of seedlings per square yard	Mean height in inches
Steam	801	2.46
Formalin	774 ±66.3	1.84 ±0.14
Control	373	1.03

Programme for 1950

CONTINUATION OF 1949 STERILISATION EXPERIMENTS

As the soil floras of the treated plots were still very reduced compared with the floras of the control plots in November, 1949, it was decided to continue the investigations into 1950. Each of the experimental plots has been divided into three sections; on the first, 1949 seedlings were lined out (on their own treatment); on the second, 1949 seedlings were left untouched (for mycorrhiza); and on the third, Sitka spruce was resown in March, 1950, without any further sterilisation treatment. Mycological samples have been obtained from the resown beds.

1950 STERILISATION EXPERIMENTS

Further experimental plots were set up in 1950 and an examination of the fungal floral of these plots will be made at intervals throughout the year. Treatments were as follows:—

(1) Steaming with Hoddesdon pipes } As in 1949
(2) Formalin }
(3) Steaming by Canopy Steamer—fifteen minutes steaming time
(4) Control.

Two plots, seven-and-a-half feet by eight feet, were set up for each treatment. Treatments were applied 15-20th March, and the plots were sown with Sitka spruce on 5th April, 1950.

EXAMINATION OF FUNGI ATTACKING ROOT SYSTEMS

An examination of the fungi attacking the root systems of Sitka spruce will also be made.

INVESTIGATIONS ON THE FAUNA OF FOREST HUMUS LAYERS

By DR. G. OWEN EVANS
Rothamsted Experimental Station

During the past eighteen months investigations on the fauna of forest humus layers have been concentrated on the qualitative and quantitative composition of the fauna and on the habits of the dominant groups of arthropods therein. The data collected from this preliminary work will form a basis for future studies on the more practicable aspect of the problem.

The present investigations may be conveniently discussed under the following heads:—

(1) Extraction methods.
(2) Ecological investigations on the mesofauna.
(3) Feeding habits and life cycles of Oribatid mites.
(4) Identification of the fauna.

1. Extraction methods

The Flotation Method for the extraction of soil arthropods is not applicable to the study of forest humus owing to the difficulty of separating the fauna from the high concentration of organic debris. A comparison between this

method and the Berlese-Tullgren apparatus has been made with soils of relatively low organic matter content. The Flotation apparatus was identical with that designed by Salt and Hollick at Cambridge except for the inclusion of a finer sieve (100 meshes per inch) in the portion of the apparatus designed by Laddell. A total of thirty two-inch diameter cores, to a depth of three inches, were collected from two square feet of the floor of a spruce stand. An equal number of samples was extracted by the two methods. The mean number of Acari and Collembola recovered per sample (9.4 cubic inches) is given below, in Table 23.

MEAN NUMBER OF ANIMALS PER SAMPLE RECOVERED BY TWO DIFFERENT METHODS

Table 23

	Berlese-Tullgren	Flotation
Acari	274.9	100.3
Sarcoptiformes	106.7	76.6
Trombidiformes	153.9	9.6
Parasitiformes	14.3	14.1
Collembola	86.8	81.7

There was no significant difference between the mean numbers of Collembola, Parasitiformes and Sarcoptiformes recovered by two methods. The Berlese-Tullgren apparatus gave a more satisfactory recovery of Trombidiformes. The serious loss of the thin-skinned Trombidiformes, predominantly *Nanorchestes arboriger* (0.18 mm. in length) and Tydeidae, during the Flotation process appeared to be due to their damage either during the washing of the soil or through contact with the sieves. The use of a 180 meshes per inch sieve did not improve the recovery rate of the Trombidiformes.

The Flotation method undoubtedly requires to be modified for the extraction of micro-arthropods, especially in the elaboration of a less drastic method of dispersing the soil. Berlese-Tullgren funnels are now used for all routine extractions.

2. **Ecological investigation on the mesofauna**

Sampling has been restricted to two main forest areas in South Bedfordshire, namely, the Commission's forest at Ampthill and the Duke of Bedford's estate at Woburn. The investigations have proceeded along two main lines:—

(*a*) An examination of the "humus" fauna of six stands with special reference to the Oribatid mites. This investigation was undertaken to determine the most important species of Oribatid mites for feeding experiments.

(*b*) Studies in the seasonal fluctuations in the mesofauna of a spruce stand at Ampthill Forest.

The six forest sites were sampled within a period of four weeks (April) in order to minimise any differences due to the seasonal fluctuations in the fauna. From each of the forests five samples (each sample 1.6 sq. cm. in surface area) were taken from two square yards of the floor. Each sample was further subdivided into the Fo (litter), F (fermentation), and H (humus) layers. Thus a total of ninety samples were examined. Data were also collected on the pH and

moisture content of each sample. All the stands were situated on sandy soils. Two complete samples from each site were examined for the total mesofauna (Acari and Collembola). The remainder were examined for Oribatei only. The results of the total extractions are summarised below, in Table 24.

NUMBER OF ARTHROPODS, IN THOUSANDS PER SQUARE YARD, IN FOREST STANDS OF SIX TREE SPECIES

Table 24

	Oak	Beech & Oak	Scots Pine	Larch	Douglas Fir	Corsican Pine
Approximate age of stand in years	200	200	90	40	25	25
Acari	304	338	195	118	225	254
Sarcoptiformes	216	254	131	76	188	158
Trombidiformes	67	61	53	35	54	78
Parasitiformes	21	23	11	7	13	18
Collembola	36	51	28	49	21	28
Total	340	389	223	167	276	282

The Douglas fir and Corsican pine records are from neighbouring stands at Ampthill Forest and recorded similar populations. The remaining sites were situated in close proximity to each other at Woburn. The deciduous forests recorded the highest population, whilst the forty year old larch stand supported a very poor fauna. The Oribatid mites were the dominant group of arthropods in all six sites.

Of a total of sixty species of Oribatei extracted, about twenty were common to the six sites. There was little difference in the qualitative composition of the dominant species irrespective of the age and type of forest.

The vertical distribution of fourteen of the common species showed rather an interesting phenomenon, in that certain species dominated in a specific layer of the "humus". Examples of three typical species are given in Table 25, below.

NUMBERS OF ANIMALS OF THREE SPECIES PRESENT IN THREE DIFFERENT SOIL LAYERS

Table 25

Species	Layers		
	Fo (litter)	F (fermentation)	H (humus)
	Average number per 1,000 *cubic centimetres of material*		
Oppia ornata (Oudms.)....	1,398	81	0
Oppia neerlandica (Mich.)	181	1,200	114
Pseudotritia minima (Berl.)	0	35	106

The results of this investigation are in preparation for publication.

The studies on the seasonal fluctuation in the arthropod fauna of a spruce stand at Ampthill commenced in January, 1950. Ten samples (3.1 sq. in. in surface area) to a depth of 2.5 in. are collected each month. In order to ascertain the vertical distribution of the fauna each sample is divided into three parts. Data are available for seven monthly series of samples. It is intended to continue this investigation for at least another five months.

3. Feeding Habits and Life Cycles of Oribatid Mites

The Oribatei are by far the most numerous group of soil arthropods, and probably play an important role in the transmutation of forest litter. Laboratory experiments with ten species have shown that the feeding habits of various members of the group vary considerably. The majority feed on fungi and algae. Species of the families Camisiidae, Carabodidae, Hermaniidae and Pthiracaridae do, however, consume decaying plant tissue. An attempt is being made to assess the amount of plant material consumed on the basis of the volume of faecal material voided. Feeding experiments to date have been made on beech and pine litter only. It is hoped to extend this work to other types of litter and to investigate the palatability of different plant materials. The writer has collaborated with Mr. P. W. Murphy of Oxford on part of this work.

A knowledge of the life cycles of these mites is of importance in understanding their seasonal fluctuations under natural conditions. The initial difficulties of culturing the Oribatei have been overcome and several species have been bred from the egg to the larval and nymphal stages.

The investigations outlined in this section are being conducted by my assistant, Mr. R. Marsh.

4. Identification of the Fauna

One of the most difficult problems connected with studies on the soil fauna is the extent to which the animals can be identified. The major groups are the Acari and the Collembola. The dearth of specialists on the former group limits outside assistance. The writer has spent much time on the systematics of the Acari, and is now able to identify a large part of the material collected. Identifications have also been undertaken for Mr. P. W. Murphy.

The position as regards the Collembola is not so serious. Dr. H. Gisin, Geneva, has given invaluable assistance with this group.

The concentrated sampling of forest humus layers has resulted in the collection of a large number of mites not previously recorded in Britain. Several records have already been sent to Dr. F. A. Turk, Cornwall, for inclusion in his *Check-list of British Acari.* In addition, at least six mites new to science have been found. It is hoped to publish descriptions of these at a later date.

SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY
Imperial Forestry Institute, Oxford

During the past year, soil faunal investigations have been concerned with the identification and assessment of the samples obtained from Experiment No. 52 at Broxa and ancillary sampling sites in the Allerston Forest area (See *Forest Research Report for* 1949 for details of this experiment). Partly on this

account, the emphasis has been on laboratory work in Oxford, and the amount of time spent in the field in Yorkshire does not compare with former years. Considerable progress has been made in this part of the work and it is hoped that at least a summary of the results and correlations with site and soil characteristics will be completed shortly. Work has continued on extraction methods, and a new apparatus has been designed in order to elucidate some of the problems and difficulties occurring in the extraction process. In addition a study of the biology and food habits of some members of the soil fauna has been initiated.

The routine aspects of the investigations may be conveniently considered under the following heads:—

(1) Experiment No. 52 at Broxa and ancillary sampling sites in the Allerston Forest area.

(2) Extraction technique

(3) Biological studies.

(4) Miscellaneous activities.

1. Experiment No. 52 at Broxa and ancillary sampling sites in the Allerston Forest Area

The major task of the present year has been a continuation of identification and assessment of the samples of these experimental sites in order to ascertain the present status of the undisturbed heathland. These data have not yet been worked up to the stage where accurate quantitative comparisons can be made, but samples of litter and humus with 30-35 organisms per gram of extraction dried material are not uncommon. When it is realised that a standard sample having 35 organisms per gram, contains approximately 750 organisms, the magnitude of the counting process will be appreciated.

Qualitatively the *Acari* material falls conveniently into the following groups:

(*a*) *Oribatei.*

(*b*) *Trombidiformes.*

(*c*) *Parasitiformes.*

The *Oribatei* are mainly saprophagous and fungal feeders, and have received most attention in soil faunal investigations as they are usually more abundant than the *Trombidiformes* and *Parasitiformes*; a contributory factor is the taxonomic complexity of the other groups. Some of the more common species present in the undisturbed heathland are as follows:

Brachychthonius brevis Mich.

Camisia segnis Herm.

Carabodes minusculus Berl. (new British record).

Chamobates cuspidatus Mich.

Melanozetes mollicomus C. L. Koch.

Oppia neerlandica Oudms.

Oribella castanea Herm.

Tectocepheus velatus Mich.

The *Trombidiformes* are a much more difficult group and show wider taxonomic variations. Little is known of their feeding habits though some are certainly predatory. The *Parasitiformes* are almost entirely predatory, the species occurring in these samples being the largest *Acari* present.

A brief summary of the more outstanding faunistic features follows:—

(*a*) *Collembola* are much less numerous than *Acari* and rarely form more than 15 per cent. of the total population. Their distribution tends to be very uneven with small populations interspersed with occasional large aggregations.

(*b*) *Acari*, on the other hand, show a more even distribution. The most striking feature here is that the individual species tend to be much smaller than those present in other habitats, a quality which renders assessment more difficult.

(*c*) The high proportion of *Trombidiform* mites which appear at certain seasons. These latter may constitute as much as 80 per cent. of the total population, the majority consisting of an extremely small mite (approximately 0.15 mm. long). The latter is a very obscure species and there is little information available concerning its biology.

(*d*) The small numbers of *Parasitiform* mites present.

(*e*) The afforested sites (Experiment No. 11 at Wykeham): Sitka spruce near canopy are faunistically richer with a tendency towards larger species, a much greater proportion of *Oribatid* mites, and a reduction in the numbers of *Trombidiformes*. On some plots in the same experiment (under birch) the earthworm *Lumbricus rubellus* has been found occasionally.

The work of identification has been materially assisted by a helpful collaboration with Dr. G. O. Evans of Rothamsted Experimental Station, and now that the main *Oribatid* species have been determined it is hoped to be able to concentrate on the *Trombidiformes* and thus complete the assessment of these samples.

2. Extraction Technique

The major project was the commencement of a more intensive investigation of the funnel method of extraction. As this is the only feasible method available for extraction of samples with high organic matter content and as it is well-known that some Arthropod members are not driven out, it was considered highly desirable to obtain information on the efficiency of the method and the mechanism involved in the enforced exodus of soil organisms. With these objects in mind a new apparatus utilizing the desiccation principle of soil extraction has been designed and constructed, and with it, it is possible to treat samples under closely controlled conditions, follow moisture and temperature changes taking place during the desiccating process, and ascertain the optimum conditions for extraction.

Some preliminary findings in the course of these investigations may be summarised as follows:—

(*a*) The error of establishing extraction conditions on the basis of tests of one individual habitat and application of these over a wide range of conditions.

(*b*) The importance of using a small sample volume.

(*c*) The necessity of undisturbed samples at least under certain conditions.

3. Biological Studies

Investigations have commenced in this sphere with the object of obtaining some information on the part played by the faunal population in the life of the

soil when considered as a medium for the growth of forest trees. The size of these organisms, too large for the techniques of the micro-biologist and yet too small for the macro-methods normally employed with insects, provides difficulties for the investigator. A technique for the larger cultures has been developed, and here collaboration and interchange of ideas with Dr. G. O. Evans of Rothamsted has been to mutual advantage.

The preliminary work has hinged on methods of culturing mites, life history studies and experiments to ascertain the food habits of some species, including the palatability of various litters, the quantities consumed and the degree of breakdown accomplished. Preliminary findings indicate that some species consume large quantities of litter when cultured under artificial conditions; some species, on the other hand, though cultured for a considerable period have not shown visible signs of feeding.

4. Miscellaneous Activities

Visual examination of the birch litter experiment established by Mr. Dimbleby at Broxa indicated a very active surface and subsurface fauna in the plots where birch litter had been applied. Samples were obtained during November, 1949, and though the number was too small to indicate quantitative trends qualitatively the 3,000 odd population count revealed some interesting features, when compared with the undisturbed heathland. *Parasitiform* mites (principally predators) were more numerous, and there were also indications of larger numbers of *Collembola* and *Enchytraeid* worms, though in the case of the latter it should be stressed that the method of extraction used is not ideal for these organisms. The writer hopes to sample these and other birch plots at a later date.

Further improvements have been made in the methods used for counting and assessing routine samples, and the writer hopes to publish a short paper on this aspect in the near future. Other activities included an exhibit staged at the 1949 Annual Meeting of the British Association for the Advancement of Science, at Newcastle-on-Tyne. This consisted of a battery of sample extractors of the split funnel type as used in routine sampling, and also photo-micrographs and slides of common soil organisms. The writer also described some features of these investigations in a short talk at a meeting of the Royal Entomological Society of London in February, 1950.

RESEARCH INTO THE PHYSICAL AND CHEMICAL PROPERTIES OF FOREST SOILS

By P. J. RENNIE
Imperial Forestry Institute, Oxford

Work continued during 1949 in the Allerston Forest Area of Yorkshire at the existing sites on Silpho and Wykeham Low Moors, but an extension was made to include certain sites at Brompton Moor and the Ellerburn valley.

Physical Investigations

The kerosine immersion method of Russell and Balcerek for the volumetric determination of soil porosity and water content proved highly successful from early samplings, but considerably time consuming owing to the soil

heterogenity demanding high sampling numbers of soil specimens. This difficulty has been partially overcome by the adoption of a large low pressure chamber capable of holding some fifteen to twenty specimens. In this way, the following sites have been continuously sampled at approximately two-monthly intervals since early 1949:—

No.	*Site*	*Vegetation*	*Cultivation*
1	Silpho Moor	Calluna vulgaris	None, natural moor
2	Wykeham Low Moor	Calluna vulgaris	None, natural moor
3	Silpho Moor	Eriophorum spp.	None, natural moor
4	Silpho Moor	None	1947. Deep R.L.R. ploughing, unplanted
5	Wykeham Low Moor	Sitka spruce close canopy	1928, Shallow complete ploughing.

and the following, in addition, from early 1950:—

No.	*Site*	*Vegetation*	*Cultivation*
6	Brompton Moor	Dense Calluna vulgaris....	1933 moderately deep ploughing
7	Brompton Moor	Japanese larch, close canopy, Deschampsia flexuosa understorey.	1933 moderately deep ploughing
8	Wykeham Low Moor	Lawson cypress and heather mulch.	1939 medium depth ploughing with subsoiling.
9	Wykeham Low Moor	Lawson cypress and dense Calluna vulgaris.	1939 medium depth ploughing with subsoiling.

These investigations are yielding interesting data on the effects of type of cultivation, tree and other vegetation, upon the moisture status and porosity of the above sites, and are under further extension at the moment.

The extensive and widely spaced sampling has only been possible by generous facilities provided by Mr. J. Simpson at Hackness Grange.

Vegetation Control and Cultivation Experiment

Assessment in late 1949 demonstrated that failures of Sitka spruce in the deeply-ploughed treatment units were considerably below those of the screefing treatment units.

Positional analysis of the failures in the screefed units showed that a greater proportion occurred in former *Eriophorum* spp. areas.

Flushing (Spring, 1950) was much earlier over deeply ploughed compared to screefed treatments.

Micro-contour Survey and Pan-Depth

The extensive practical work of these two projects has now been completed and the data are being collated and analysed.

Survey of Moorland Vegetation

The detailed map of the field data has now been completed and constitutes a valuable record from the viewpoint of the above experiment, and in quantitatively specifying the moorland type.

Chemical Investigations

Improved laboratory facilities during 1949 enabled greater progress to be made under this section. Work on the distribution of total and available nutrients throughout the soil profile has continued on a number of sites.

Ammonification in Litter Horizon

A preliminary trial of three sites indicated that at Wykeham Low Moor ammonification was greater under birch than Sitka spruce, but in both instances it was considerably greater than under *Calluna vulgaris*. Nitrification was so small as to require further study.

Litter Composition

The litter horizons of the following species growing over the same geological formation have been analysed for nitrogen, potassium, phosphorus, calcium, magnesium, and manganese:—

Sitka spruce
Corsican pine
Japanese larch
Scots pine
Pinus contorta
Birch
Calluna vulgaris

Similar analyses carried out on Sitka spruce, over a series of sites giving a range of growth rates, demonstrated that there was a considerably richer litter under the better growing trees.

Miss S. Russell continued to give invaluable assistance in the analytical work.

Meteorology

A climatological station, in accordance with Meteorological Office specifications, has been established at Silpho Moor, an evaporation tank being installed in addition to the usual instruments. One interesting point in the establishment of this Station was the conversion of a plot of *Calluna* moorland into a grass ley.

NUTRIENT UPTAKE OF CONIFERS

By Dr. L. LEYTON
Imperial Forestry Institute, Oxford

Investigations carried out in the Physiology section have been concerned mainly with the mineral nutrient relations of trees as influenced by soil conditions. Special attention has been directed towards growth and nutrition on *Calluna* dominated sites (heather moors). In 1949, two field experiments were laid out, one in Scotland (Clashindarroch Forest, Aberdeenshire), the other in Yorkshire (Allerston Forest) to compare the effects of screefing and graded applications of phosphatic fertilizer on the growth and nutrient status of Sitka spruce and Scots and Corsican pines. The first sampling was made

at the end of 1949 growing season. Results obtained to date suggest that the checking of spruce by *Calluna*, and the relative immunity of pines, can be explained in terms of the rooting habits of these species, and their mineral nutrient relationships. It would appear that, whilst phosphorus deficiencies in the soil are contributory towards poor tree growth on these sites, the growth of spruce is more intimately related to its nitrogen nutrition. Significant relationships have been established between the nitrogen status of *Calluna*, and the growth and nitrogen status of spruce, but not in the case of pine. These findings support deductions made from observations in the rooting habits of these species.

Attempts have been made to extend these investigations by a study of the mineral nutrient status of *Calluna* growing in different plant communities, which, according to experience, possess different potentialities for tree growth (Special study H. S. Yang). Whilst the investigations are still in the preliminary stage, there are definite indications that the nutrient status of *Calluna* can, under certain conditions, be a useful guide to soil fertility.

To investigate the effect of pH on the growth of Sitka spruce seedlings, two series of water cultures were set out in 1949. In one series nitrogen was supplied as NH_4 (ammonium salts), in the other as NO_3 (nitrates). Except for pH, each series was identical with regard to the supply of nitrogen, phosphorus, potassium, calcium and magnesium. Under these conditions maximum growth was obtained between pH4 and 5, the NO_3 (nitrate) seedlings showing slightly better growth than the NH_4 (ammonium salt) seedlings. At the extreme pH values (3 and 7) growth was markedly reduced, with pronounced abnormalities in root growth developing in the most acid-solutions. It is hoped to continue these experiments with a number of our most important tree species.

ECOLOGICAL STUDIES ON CALLUNA HEATHS

By G. W. DIMBLEBY
Imperial Forestry Institute, Oxford

There is a good deal of evidence for believing that the difficulties experienced in afforestation on *Calluna* heaths at Broxa, Allerston Forest, Yorkshire, arise from two main causes, *Calluna* (heather) competition and podsol profile. The first of these being investigated on the undisturbed moorland, with particular reference to the distribution of heather roots in relation to tree roots. Tree regeneration, when heather is temporarily eliminated by fire, has also been made the subject of detailed study, and is clearly closely linked with *Calluna* competition.

The detrimental properties of the podsol itself are deserving of particular attention, and in order to get this approach in perspective much trouble has been taken to establish how long podsolisation has been active, and what soil type gave way to it. The conclusion reached is that about 2,500 or 3,000 years ago, the plateaux were covered with a forest of oak, birch and hazel, whilst alder, lime and elm (on the heavier soils) had been present in high proportion during the preceding wetter Atlantic period. The soil was a brown forest soil, practically unleached.

Bronze Age man destroyed this forest, which was rapidly replaced by heather. Podsolisation was the result, and has gone on unchecked ever since. It has resulted in a rigid stratification of plant nutrients, so that all root systems are forced to operate in restricted zones; competition is therefore inevitable. Ploughing alone is not a satisfactory answer to this, since it has been clearly shown by the Czecho-Slovakian investigator Nemec that a redistribution of nutrients into horizons rapidly takes place again as long as a podsolising vegetation (e.g., heather or most coniferous trees) is maintained.

One marked effect of the podsol is its influence on water retention. On Broxa Moor a marked contrast can be demonstrated between a pinewood soil, which in 1949 showed drought conditions throughout the profile by May, and a regenerated hardwood soil of the same origin, which did not reach drought conditions at the surface till July, whilst even then the lower horizons retained adequate moisture. There can be no doubt that the lack of incorporated humus in the podsol is one of the main causes of its infertility, not merely as a source of nutrients, but also in its effect on soil structure and microbiology.

This work has been carried on in close liaison with Mr. Rennie, whose analyses of the physical and chemical properties of these soils are proving invaluable and dovetail in admirably with the ecological investigations.

On the grounds stated above, and many others too, it is held that a podsol is an undesirable soil type for tree growth. Moreover, it is dynamic; and it is steadily getting worse—a point to ponder when considering long term afforestation. There is, however, some hope, since seldom, if ever, is a podsol inevitable in this country. Severely podsolised though the Broxa soils are, it can be shown that, even here, there are small stands of natural hardwood (with attendant richer ground flora) under which soil improvement has set in. It appears that within one generation from the colonisation of moorland there is an increase of pH of one unit, the leached layer becomes enriched in incorporated humus, and disintegration of the pan allows root penetration deeper into the soil.

A strong case can therefore be made out for either an improvement crop prior to planting a timber crop; or the use of hardwood—conifer mixtures, which, in the correct proportions, should allow some merchantable timber to be produced without running the risk of reducing these soils to complete sterility.

In the belief that sooner or later this approach will be necessary to preserve what little fertility the soil has, field experiments have been started to investigate the following points:

(*a*) Means of establishing birch, which is the natural hardwood pioneer of these moors.

(*b*) The effect of birch litter on the moorland soil.

(*c*) What other species of hardwoods show promise of successful establishment, and their relative properties as soil improvers.

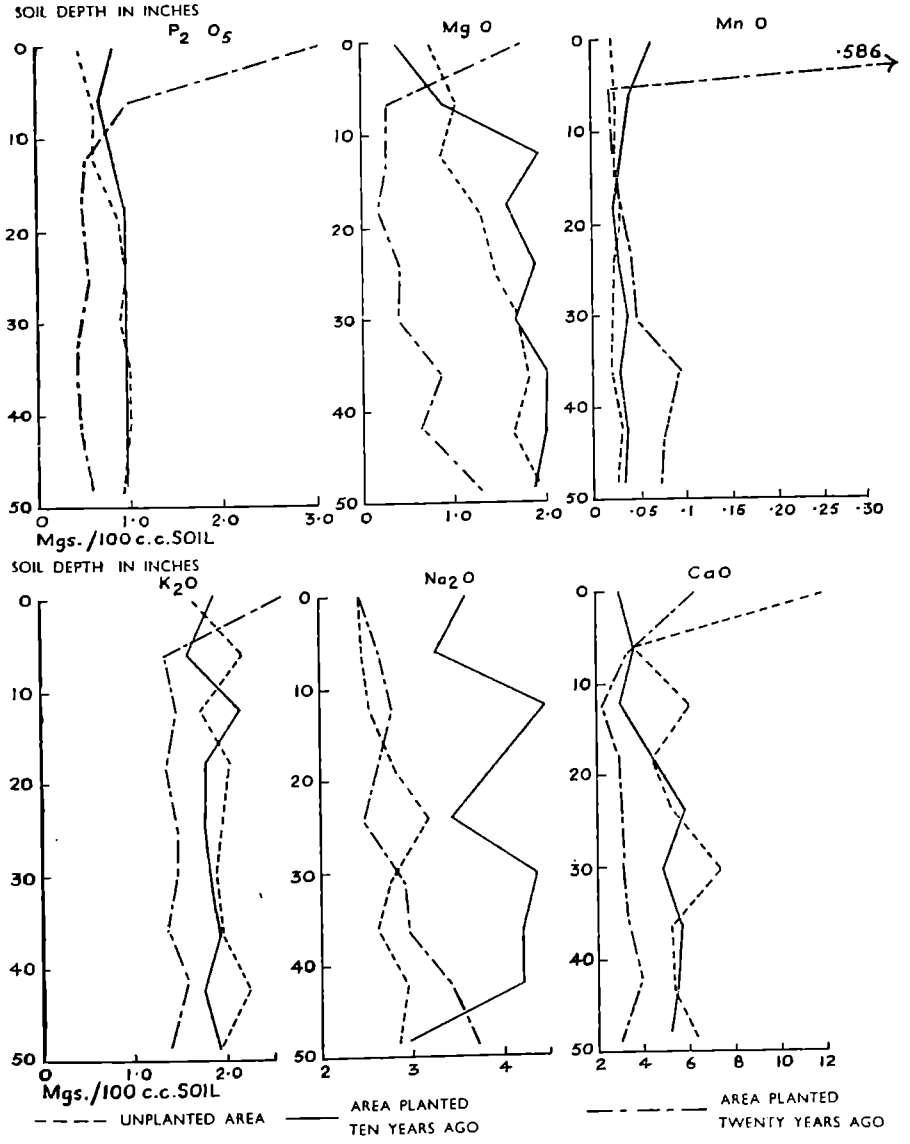
ECOLOGICAL STUDIES IN PINE PLANTATIONS

By Dr. J. D. OVINGTON
Macaulay Institute for Soil Research, Aberdeen

The investigation of the ecological changes that occur when Corsican pine is grown on the sand dunes at Culbin Forest on the north coast of Morayshire has been continued.

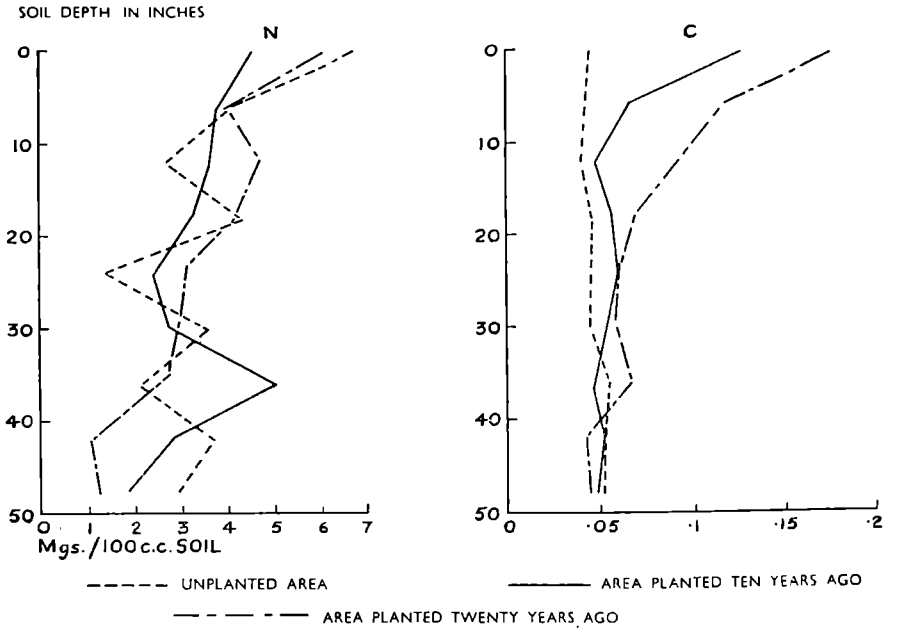
ECOLOGICAL STUDIES IN PINE PLANTATIONS, BY J. D. OVINGTON

FIGURE V



ECOLOGICAL STUDIES IN PINE PLANTATIONS. BY J. D OVINGTON

FIGURE VI

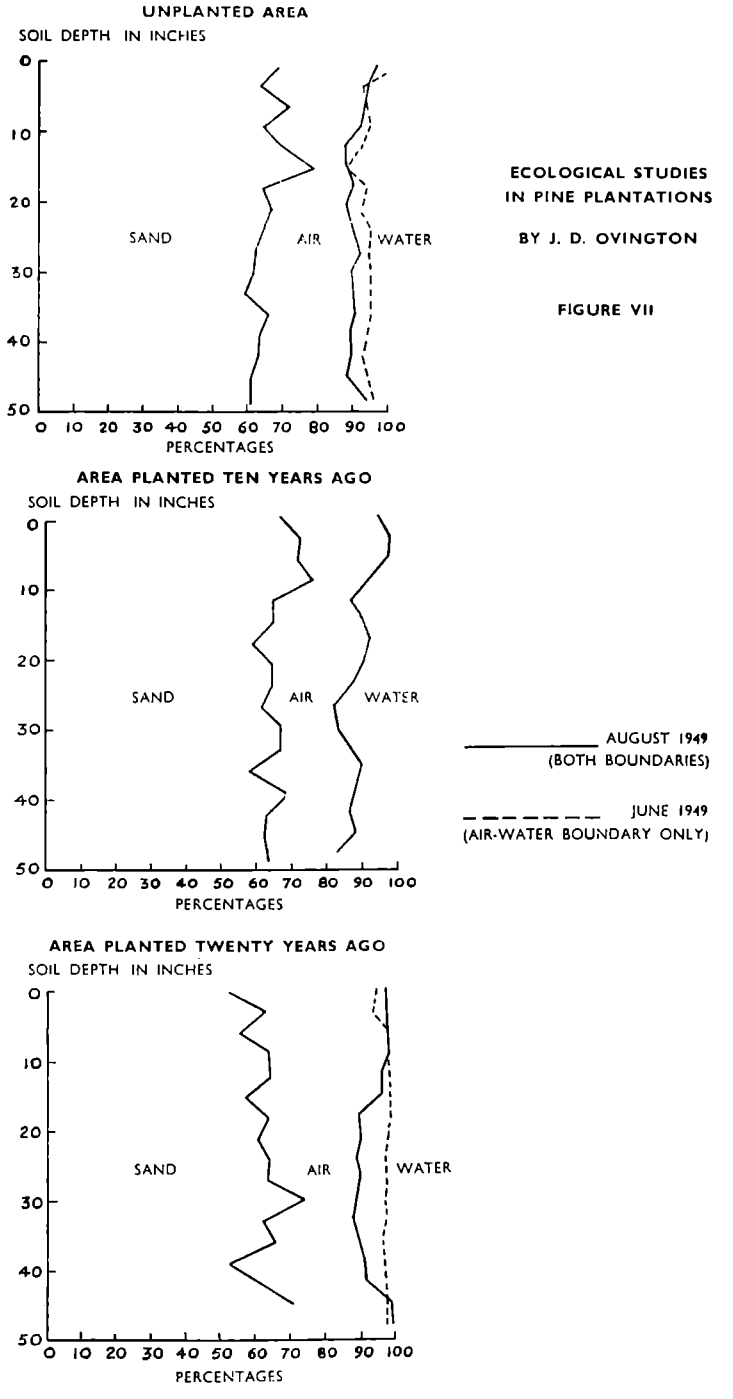


Within the first twenty years of planting, profound ecological changes have been recorded. In the afforested areas the flora becomes restricted, but in contrast the micro-flora is more varied and abundant.

Estimations of sand grain size, pH, carbon, loss on ignition, nitrogen, phosphate, calcium, sodium, magnesium, manganese, and potassium have been completed on soil samples from plantations of various ages. After afforestation there is a general decrease of available nutrients in the lowermost sand, but frequently an increase in the surface sand layers immediately below the litter. The percentage volumes of sand, water, and air, in the soil of these plantations, have been determined, and are shown in Figure VII. From these results the total amounts of available nutrients (i.e., P, Mg, Mn, K, Na, and Ca), carbon and nitrogen, in the soil volume to a depth of four feet (1.22 metres) for one square metre surface have been calculated, and are shown in Figures V and VI.

The plant and soil water relationships of the dunes are complex. Since the water table is too low to supply moisture directly to the trees, they are dependent upon precipitation for water. The rainfall is low, and there is a high evaporation rate, so that the availability of water may become a limiting factor to tree growth. An area has been investigated in which tree growth and root development can be correlated with the supply of water. After dry and wet periods the total soil water present in the plantations is less than on adjacent unplanted areas.

A similar investigation has been continued at Tentsmuir Forest, north-east Fifeshire. The Tentsmuir quadrats are located on a low lying sand flat dominated by *Calluna vulgaris* (heather) and have been planted with Scots pine. The soil samples collected from Tentsmuir are being analysed and compared with those from Culbin. As a result of the higher water table and the long



established ground flora at Tentsmuir, soil conditions are quite distinct from those at Culbin. The available nutrient content of the sand is comparable with that of Culbin, but at Tentsmuir there is an accumulation of nutrients

immediately above the water table. The effect of afforestation is to lower the water table and bring about a redistribution of nutrients.

In an experiment begun in association with Mr. Oliver, Conservator for East Scotland, on the establishment of vegetation on the Culbin Sands, metre quadrats were marked out for each treatment. Records of the number of seeds germinating and degree of tillering were made. Despite heavy grazing, grasses, particularly the fescues, produce the most complete vegetational cover within the first year.

BOTANICAL STUDIES OF VARIATION IN CERTAIN CONIFER SPECIES

By DR. E. V. LAING
Department of Forestry, Aberdeen University

The work on morphological variation in Scots pine with a view to determining races has been continued. Data have been obtained on several points, particular importance being now attached to length of needle, breadth and thickness of needles, relationship between pith and wood diameter of the current year's shoot. Variations have also been noted in colour of male flowers, cone structure, seed and ratio of length to breadth of wing. The study of the pith has required some considerable fundamental research as it has been found that measurements vary according to the position in the shoot. Since his appointment, Mr. A. Carlisle has taken over most of the investigation into Scots pine.

Attention has now been more intensively directed to Douglas fir and Sitka spruce, and already it is very evident that there are several definite types of Douglas fir determined on morphological characters. These may be tentatively enumerated as follows: arrangement of needles, thickness of needle, continuity of hypoderm, presence or absence of papillate cells, presence or absence of stone cells, colour of both male and female flowers, shape of ovuliferous scale, length of bract scale. It may be possible to distinguish bark types.

Sitka spruce so far seem to show bark differences, cone differences and often variation in stomatal development.

FOMES ANNOSUS IN EAST ANGLIAN PINE PLANTATIONS

By S. D. GARRETT
School of Botany, Cambridge University

Dr. J. Rishbeth left Cambridge at the end of 1949 to take up an appointment in Jamaica as Plant Pathologist to the West Indian Banana Research Scheme, but six experiments which he set up before leaving are being sampled and recorded by the Cambridge Botany School. These six experiments fall into two groups of three each.

The first group of three experiments is concerned with protection of the cut surface of pine stumps against basidiospore infection by *Fomes annosus* (the fungus causing conifer heart rot) by painting the surface, immediately after felling, with a preservative. The preservatives being tested are paint, creosote, and a tar-creosote mixture (2 tar : 1 creosote). The recording of these experiments is not yet complete, but the tar-creosote treatment has given promising results, the incidence of *Fomes* infection having been reduced to 3% of the stumps so treated.

Whereas in the first group of experiments, the protection against *Fomes* infection may be described as "passive", the protection envisaged in the second group of three experiments may appropriately be denoted as "active", through deliberate inoculation of the stumps with the fungus *Peniophora gigantea*, a natural competitor of *Fomes*. Even in the absence of inoculation, *Peniophora* exerts a natural check upon stump infection by *Fomes*. The object of stump inoculation with *Peniophora* is to increase the effectiveness and extent of the natural "biological control" of *Fomes* by a competitor. Inoculation has been effected (1) by driving in wedges of wood infected with *Peniophora* and (2) by spraying with a suspension of *Peniophora* basidiospores. If this method of biological control should prove effective, the cost need not be prohibitive, because the first batch of stumps inoculated with *Peniophora* would provide ample inoculum for later fellings, and the process would become a continuous one; once such a scheme of control had been launched, supervision by a trained mycologist should become superfluous, because *Peniophora gigantea* is an easy fungus to recognise, and the danger of confusion with other fungi would probably be negligible. Results from this group of experiments will not become available until the end of 1950.

The work carried out by Dr. Rishbeth on the epidemiology and control of the *Fomes annosus* disease in East Anglia will be published in full, very shortly, as a series of papers in the *Annals of Botany*. An account of some aspects of this work is being prepared by Dr. Rishbeth for *Forestry*.

ORNITHOLOGICAL INVESTIGATIONS IN FORESTS

By Dr. D. LACK
Edward Grey Institute for Field Ornithology, Oxford

Work on the nesting of titmice, started on a big scale in 1948, was repeated in the same areas in 1949, i.e., the Forest of Dean, Thetford Forest, East Anglia, and Alice Holt Forest, Hants., and in addition, in two new areas, Gwydyr Forest, Caernarvonshire and Glentress Forest, Peebles-shire. As in 1948, observations were undertaken by the adjacent Forester Training School, except at Alice Holt where they are carried out by Charterhouse School Natural History Society. Parallel observations were also made at Wytham, Oxford, by J. A. Gibb; near Guildford, Surrey, by the Farm Institute, Merrist Wood; near Sway, New Forest, Hants., by E. Cohen, and in Fifeshire and around Perth by J. M. D. Mackenzie. The observations were entered up on the Nest Record Cards, designed by the British Trust for Ornithology and have been deposited at the Edward Grey Institute, Oxford.

In those areas studied in both 1948 and 1949, the titmice showed a marked increase in the second year, and the total number of Nest Record Cards received was, therefore, much greater in 1949. The analysis of the data has revealed some interesting facts, though most of the conclusions must be considered provisional until the results for a few more years are available. The breeding season was earlier in the broadleaved woods of the Dean, Alice Holt and Oxford than it was in the conifer plantations in East Anglia. In the latter, breeding was appreciably earlier in Scots than Corsican pine. Clutch-size was lower in 1949 than in 1948, and also varied somewhat in the different woods. It also declines as the season progresses. Nesting success was extremely high in all areas except Thetford and Tentsmuir Forest, Fifeshire, where there was an abnormal 50 per cent. mortality among blue and great tits, many of which died of starvation in the nest. By the end of 1949 the number of Nest Record Cards received were: Great Tit—557, Blue Tit—482, Coal Tit—136.

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