FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1953

LONDON: HER MAJESTY'S STATIONERY OFFICE
1954

FIVE SHILLINGS NET

SELECTED
FORESTRY COMMISSION PUBLICATIONS

GUIDE BOOKS
(Illustrated)

BEDGEBURY (NATIONAL PINETUM AND FOREST PLOTS). (70-636.) 2*s.* 6*d.* (2*s.* 8*d.*)

NEW FOREST. (71-9*.) 3*s.* 6*d.* (3*s.* 9*d.*)

BOOKLETS

No. 1. WOODLAND MOSSES (Fully Illustrated). (71-6-1.) 2*s.* 6*d.* (2*s.* 7½*d.*)

No. 2. THE DEDICATION OF WOODLANDS: PRINCIPLES AND PROCEDURE. (70-516-2-50.) 2*s.* 0*d.* (2*s.* 2*d.*)

No. 3. CHESTNUT BLIGHT CAUSED BY THE FUNGUS ENDOTHIA PARASITICA. (70-516-3.) (Illustrated in colour). 2*s.* 6*d.* (2*s.* 7½*d.*)

FOREST OPERATIONS SERIES

No. 1. THE THINNING OF PLANTATIONS. 2nd Edition, 1951. (70-482-1-51.) 1*s.* 3*d.* (1*s.* 4½*d.*)

No. 2. THE ESTABLISHMENT OF HARDWOODS BY SOWING OR PLANTING. (70-482-2.) 1*s.* 6*d.* (1*s.* 7½*d.*)

LEAFLETS

No. 1. THE LARGE PINE WEEVIL. 6*d.* (7½*d.*)

No. 2. ADELGES COOLEYI, AN INSECT PEST OF DOUGLAS FIR AND SITKA SPRUCE 4*d.* (5½*d.*)

No. 3. PINE SHOOT BEETLES. 2*d.* (3½*d.*)

No. 4. THE BLACK PINE BEETLE (HYLASTES ATER) AND OTHER CLOSELY ALLIED BEETLES. 6*d.* (7½*d.*)

No. 5. CONIFER HEART-ROT. 2*d.* (3½*d.*)

No. 6. HONEY FUNGUS. 6*d.* (7½*d.*)

No. 7. ADELGES ATTACKING SPRUCE AND OTHER CONIFERS. 6*d.* (7½*d.*)

No. 12. INCOME TAX AND DEATH DUTIES ON WOODLANDS 6*d.* (7½*d.*)

No. 14. PHOMOPSIS DISEASE OF CONIFERS. 2*d.* (3½*d.*)

No. 16. LARCH CANKER. 2*d.* (3½*d.*)

No. 17. CHAFER BEETLES. 6*d.* (7½*d.*)

No. 18. TWO LEAF-CAST DISEASES OF DOUGLAS FIR. 6*d.* (7½*d.*)

No. 19. ELM DISEASE (CERATOSTOMELLA ULMI). 6*d.* (7½*d.*)

No. 20. WATERMARK DISEASE OF THE CRICKET BAT WILLOW. 2*d.* (3½*d.*)

No. 21. LEAF CAST OF LARCH. 3*d.* (4½*d.*)

No. 23. PIT-PROPS. 2*d.* (3½*d.*)

No. 25. REPLANTING OF FELLED CONIFEROUS WOODLAND IN RELATION TO INSECT PESTS. 6*d.* (7½.*d*)

No. 26. THE SPRUCE BARK BEETLE. 6*d.* (7½*d.*)

No. 27. POPLAR PLANTING. 4*d.* (5½*d.*)

No. 28. COLLECTION AND STORAGE OF ACORNS AND BEECH MAST. 4*d.* (5½*d.*)

No. 29. PISSODES WEEVILS. 6*d.* (7½*d.*)

No. 30. SOOTY BARK DISEASE OF SYCAMORE. 9*d.* (10½*d.*)

No. 31. THE GREY SQUIRREL: A WOODLAND PEST. 9*d* (10½*d*)

No. 32. PINE LOOPER MOTH (BUPALUS PINIARIUS). 9*d.* (10½*d.*)

Binders for leaflets (71-8) are available price 1*s.* 3*d.* (1*s.* 4½*d.*)

(*continued on cover page iii*)

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1953

LONDON: HER MAJESTY'S STATIONERY OFFICE
1954

ADDRESSES OF PRINCIPAL
RESEARCH OFFICES OF THE FORESTRY COMMISSION

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

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

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

CONTENTS

PART I: WORK CARRIED OUT BY FORESTRY COMMISSION STAFF

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, unfortunately, must start with a reference to the death of the Chairman of the Forestry Commission, Lord Robinson, which took place on the 5th of September, 1952. From his earliest days as a forest officer he was conscious of the value of research in the solution of the many problems which confronted pioneer silviculturists in Great Britain and when he came to a position in which he could influence events, he made certain that research played an important part in the great developments in forestry which followed the conclusion of the first world war. To the end, he maintained the closest interest in forest research, keeping himself posted in new developments, and he was always ready to help and advise even the youngest research officer.

During the year, two new District Officers have been appointed—Mr. R. Lines and Mr. A. F. Mitchell. Mr. L. Reynolds, assistant Utilisation Officer, resigned in June 1952 and was succeeded by Mr. J. R. Aaron, who was appointed in November of that year. The Commission also lost the services of Dr. A. A. Zukowski, who held a temporary appointment as District Officer.

Sir William G. Ogg, Director of the Rothamsted Experimental Station, and Dr. J. W. Gregor, Director of the Scottish Plant Breeding Station, joined the Advisory Committee on Forest Research. This Committee is now composed of the following members:

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

The Committee held one meeting during the year, in London.

The sub-Committee on Nursery Nutrition, under the Chairmanship of Professor Steven, held a meeting in Edinburgh on 14th and 15th November, 1952, to review the programme of work. Visits were paid to the nurseries at Tulliallan and Devilla in Fife.

Dr. S. D. Garrett of the Botany Department, University of Cambridge, joined this sub-Committee, which now consists of Professor Steven; Mr. Jacks; Dr. E. M. Crowther, Rothamsted; Dr. A. B. Stewart, Macaulay Institute, Aberdeen; Dr. Ida Levisohn, Bedford College, London; and Dr. Garrett. As before, a heavy burden has been carried by Dr. Crowther and his colleagues and by Dr. Stewart, and our thanks are due to them for the great help which they have given.

Towards the end of 1952, the Commissioners set up a Committee, under the Chairmanship of Sir Richard Cotterell, Bt., to study the distribution, spread and control of the grey squirrel and to consider what further investiga-

tion or research might be necessary. One of the first steps taken by this Committee was the appointment of a young man from one of our Forester Training Schools to the Commission's Research Station, to investigate methods of trapping destruction. It is expected that further work on the habits and numbers of this animal will be carried out under the guidance of this Committee.

As before, contact has been maintained between the Research Branch and Universities and other Institutions which are engaged in research in forestry, or in subjects bearing upon it, while the Commission continued to take part in the work of the International Union of Forest Research Organisations. The Director attended the meeting of the Permanent Committee of this body held in Denmark in September, 1952. The Chief Research Officer, Mr. M. V. Laurie, attended the sixth Commonwealth Forestry Conference in Canada, in the autumn of 1952; and two of our research officers were present at the Danish Orcadian Conference in the Orkney Islands in July 1952, when they described the experimental planting in the north of Scotland and took part in a discussion on shelter belts. An increasing part is now being taken by research officers at the meetings of technical and scientific societies.

Much help has been received from the Director and staff of the Forest Products Research Laboratory, who are continuing to carry out tests on home grown timber.

This report, as usual, is divided into two sections and is prefaced by a summary written by the Chief Research Officer. In the section dealing with the work of the Forestry Commission staff, there are no major developments to record but preliminary reports have been included of two special surveys, one following the great gale of 31st January, 1953, and the other an investigation of plantations on coal wastes in different parts of the country.

In the section on work carried out by other institutions, attention is drawn to a report on an investigation of the new disease of sycamore, caused by *Cryptostroma corticale*. During the year a grant was made to the University of Edinburgh for an investigation of shelter and shelter plantations in Central Scotland.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE
Chief Research Officer

Visits

During the year the number of visitors to the Research Station totalled 250, and included people from Algeria, Argentina, Australia, Austria, Canada, Cyprus, Denmark, Egypt, France, Germany, Holland, India, Nigeria, Norway, Spain, Sweden, Thailand and the United States of America.

Visits were paid to the several experimental areas on peatland and heathland afforestation by members of the Danish-Orcadian Conference, the Crofting Commission, forestry students of the Universities of Aberdeen, Edinburgh and Wales; parties of District Officers from Scottish conservancies; Ministry of Agriculture officers from northern England, and forest officers and students from Sweden, Denmark, Kenya, Southern Rhodesia and Pakistan.

Members of the Royal Norwegian Forestry Society visited the larch provenance and other experiments at Drummond Hill Forest.

The Season

The year was notable for a very severe gale on January 31st, 1953, which caused such devastation to woodlands in the north-east of Scotland that a special enquiry was instituted ; the findings are presented further on. A severe gale from the north-west was also recorded on December 16th/17th, 1952, and it caused damage especially in the west. Late spring frosts at the end of May and beginning of June 1952 caused considerable damage in southern Scotland. Early autumn frosts were again noticeably absent. In general the winter was not severe and there was little snow. The spring of 1953 was unusually mild and dry.

The Year's Work

As formerly, this report is divided into two parts, namely:—

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

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

Forest Tree Seed Investigations

795 germination tests on tree seed samples were carried out. About one fifth of these were done by the tetrazolium vital staining technique. Investigations into the reliability of the tetrazolium test continued for the fourth year, and we are now satisfied that we can obtain reliable and consistent results with it for Sitka spruce, Norway spruce, Scots pine, Corsican pine, European larch and Douglas fir. Results with Japanese larch have been less satisfactory.

Pre-chilling of seed of certain species has been found to reduce the time for germination very greatly, (e.g. from 40 or 50 days down to 14 days), provided moisture conditions are suitably controlled during pre-chilling.

The identification of seed-borne fungi which give trouble in the germinators has continued. Methods of control are being investigated.

Seed storage investigations show that acorns can be stored in moist peat for two years, with little loss in viability. Attempts to store beech mast for more than eighteen months have failed. Successful long term storage of conifer seed requires the seed to be a little below 10 per cent moisture content before sealing up in airtight containers, and best results have been obtained at a constant temperature of 36°F.

Experimental Work in Nurseries

Partial Sterilization of the Soil

A large scale steam sterilization experiment, using 150-square-foot treatments, was successfully conducted in Scotland. It confirmed the 1951 work and again emphasized the superiority of steam over formalin as a soil sterilizing agent; but the trouble and cost rule it out in comparison with chemical methods. 'D-D' soil fumigant was again less effective than formalin as a soil sterilizer, in spite of the use of a technique to permit easier diffusion of the chemical throughout the soil. Second year residual effects of 'D-D' were negligible and of no practical consequence. Large scale user trials with formalin failed to produce the expected result. The reason for this is not yet known. Formalin powder (commercial formalin absorbed in a powdered mineral carrier) was more effective than the standard formalin solution at Fleet Nursery (Kirkcudbrightshire) whereas the converse was true at Newton (Morayshire). A small trial of chloropicrin gave indications that this chemical may prove to be a useful soil sterilizing agent.

Manuring

Placement of phosphate and potash below band-sown seed produced the taller seedlings when compared with broadcast seed over broadcast fertilisers. Seed in this experiment was sown at two densities, but even so the yield of seedlings per pound of seed was lower both with placed fertilizers and with band sowing than with broadcast methods. An experiment comparing the application of phosphate fertilizers, sixteen, five and two weeks before sowing, and on the date of sowing, indicated that applications two to sixteen weeks before sowing are most successful. Applications on the date of sowing, and particularly where the fertilisers are left in contact with the seed, reduced the speed of germination and the final yield of seedlings. Experiments comparing methods and times of applying nitrochalk showed that applying one third of the total ($4\frac{1}{4}$ cwts. per acre) before sowing, with two subsequent top dressings in August, or one in August and one in July, produced very slightly larger plants than did other methods.

Four long-term fertility demonstrations were either started or continued. At Teindland heathland nursery (Morayshire) the best crop of plants in the third year was obtained from artificial fertilizers alone. Compost plus artificials, and compost alone, produced smaller and fewer seedlings both at Teindland and at Bramshill (Hampshire).

Other Seedbed Operations

Compaction of seedbeds with a $3\frac{1}{4}$ cwt. roller, and light rolling after sowing, produced slightly earlier germination and an increase in numbers of plants, when compared with lighter compaction and no rolling after sowing.

A covering of hessian over seed sown below a grit cover slightly increased the speed of germination, the height of seedlings, and the yield of plants.

'Krilium' soil conditioner applied to seedbeds made up on heavy soil reduced the speed of germination, and had no beneficial or adverse effect on height growth or seedling yields. There was some evidence that frost lift had been slightly reduced by applications of 'Krilium'.

An experiment to determine a suitable method of applying magnesium to a soil suspected to be deficient in magnesium was a partial failure. Magnesium deficiency symptoms which were apparent in seedlings in 1951 did not reappear even on untreated ground in 1952.

Seedbed irrigation experiments at Kennington Nursery near Oxford showed dramatic increases in the numbers of seedlings and their growth in this abnormally dry summer. At Widehaugh Nursery (Northumberland), however, results were almost completely negative. There seems to be some other factor limiting seedling growth there.

A successful attempt was made to raise three crops of Sitka spruce seedlings in one year in the same heated frame. Seedlings were grown in soil heated by electrical bottom heat. Plants were hardened off out of doors, and a 3 inch cover of spruce branches 6 inches above the seedlings proved satisfactory even in February. The use of night illumination produced slight responses in height growth in Scots pine, and considerable responses in Norway and Sitka spruce. Illuminations of four and five foot-candles were used.

Root pruning one year old Scots pine and Japanese larch at a depth of 3 inches in the second year led to a lower mean height of seedlings, a greater root/shoot ratio by weight, and more root fibre, when compared with unpruned seedlings in each case. But comparable one-plus-one transplants, with the same total age as the two-year-old seedlings mentioned above, were even shorter in height, and had even more root fibre.

Experiments in weed control in seedbeds by chemical means were extended. The value of pre-emergent applications of vaporising oil was confirmed over a wide range of conditions. A number of other oils and chemicals were tested both as pre-emergent and post emergent applications. Though promising results were obtained in many cases, we are not yet in a position to be able to recommend a safe post-emergent treatment.

Experiments to determine the effect of very early lining-out indicate that for Scots pine and Sitka spruce, lining-out in July and June can be highly successful if weather and soil conditions are suitable.

Maleic hydrazide reduced the amount of second-year height growth of several conifers, as intended, but did not delay the date of flushing.

Silvicultural Investigations in the Forest

DERELICT WOODLANDS

In the series of experiments comparing different methods of treating derelict woodlands on varying soil types, bearing different types of woody regrowth, two new experiments were added, bringing the total to five. All operations were costed, and the same initial results obtained, namely that clear cutting is the most expensive, costing up to £55 per acre; though, depending upon the saleability of the produce, the nett cost may be very low. In strip or group clearing the initial costs are much lower, but this may be largely counteracted by higher tending costs later on. Varying degrees of intensity of planting are being compared, from complete planting of cleared areas, to enrichment of existing regrowth using single large plants. On suitable sites, the use of conifers in mixture with hardwoods to give earlier returns is being tried.

TRIAL PLANTATIONS ON DIFFICULT SITES

This aspect of silvicultural research is involving more and more work now that the main technical problems of most heathland and peatland afforestation have been solved. The types of ground now being tackled are those that have hitherto been classed as unplantable, on account of exposure, soil conditions, or atmospheric pollution. In exposed areas, the technique of building up shelter, either to protect agricultural ground or as a screen behind which to raise plantations, is being studied; and a number of trial plantations of shelter belts and shelter blocks have been laid down in Caithness and in the Shetland Islands. In smoke polluted areas in the Midlands three years of experimental planting have been completed. *Pinus contorta* features largely as the basic species on all peat and *Calluna* heath types, and it is interesting to note that on poor deep peat the earlier plantings have grown at a rate corresponding to Quality Class II Scots pine, while on the same area Scots pine itself only attained Quality Class III. Some experimental planting has been done on sand dunes, and on some heathland in Cornwall which has proved particularly difficult, and studies have been made of the results of planting on opencast ironstone workings and colliery waste tips.

PLOUGHING AND MANURING

Trials were made of an Australian type of stump-jump disc plough combined with sub-soiling, in order to provide a larger volume of loosened soil for root development.

In an attempt to bring Sitka spruce out of check on a *Calluna* heath, applications of fertilizers containing nitrogen produced only an ephemeral response. The only treatment that has shown definite results is cutting the *Calluna* and mulching the plants with it, but this is not an economic operation.

DRAINING

Trials of Norwegian methods of making drains by explosives were not entirely successful, as sympathetic detonation could not be obtained in the mineral soil in which the tests were done. A wet peat or waterlogged soil is necessary for this. Individual fusing of each charge would render the operation uneconomic.

SPECIES TRIALS

A wide range of additions was made to species trials in different localities, and some mixture plots were included. The Benmore (Argyll) Forest Garden, consisting of small plots of many different species, was replanned three years ago, and the new form of the garden is now taking shape. Sixteen new plots were planted in the current year, bringing the total up to 161, of which 35 plots will have to be replaced.

Work on establishing experimental plantations of hardwoods in Scotland continued. Plots of ash, red oak, beech, gean, wych elm, lime, sycamore and Japanese chestnut were laid down at two sites in Dumfries-shire. In addition an experiment was established to compare gean, wych elm, Norway spruce and European larch as nurse species for twelve or more plant groups of pedunculate oak.

Ecological studies were largely confined to derelict woodland sites on clays and clay-loams, though studies were also made of southern heaths in Dorset and Cornwall, and of the serpentine soils on the Lizard peninsula.

PROVENANCE STUDIES

An experiment carried out in the nursery to compare the growth of normal

commercial supplies of Japanese larch seed with that of a special collection from Mount Fujiyama showed no important differences, though the indications were that the Fujiyama collection, in spite of having larger seed, grew more slowly and less vigorously. In the International European Larch Provenance trials planted in 1945, an assessment of the intensity of attack by various insect pests showed some variation between the different origins in the relative damage sustained. A beech provenance trial, which includes specially selected strains from Belgium, Holland, Germany, Czechoslovakia, Denmark, France and Austria, as well as some of the finest British origins, has been planted in the Chilterns alongside plants of the local Chiltern strain. This should provide interesting evidence on the question of whether the Chiltern beech has become degraded through adverse selection in the past. Scots pine provenance experiments using strains expected to be able to stand sea-winds better than normal have been planted in western Scotland.

Rhododendron ponticum in British Woodlands

Rhododendron ponticum, which has become such a serious pest in many British woodlands, was studied by the Ecologist, and useful information obtained on the rate of spread from seed and by vegetative means, and on the factors affecting the spread. Observations on shade tolerance under tree crops were also recorded.

Colliery Spoil Heaps

A brief account is given of the main points arising from a survey of tree growth on colliery spoil heaps. These heaps are not nearly as infertile as is frequently imagined, and they usually provide sufficient moisture to support tree growth. Planting difficulties are due mainly to such factors as exposure, and commonest of all, vandalism by the local population in industrial areas. A wide range of species has been successfully planted on lower and less exposed heaps. Care has to be taken in the choice of species for certain conditions such as smoke polluted areas, and for heaps that are acid or have been burnt.

Damage by the Gale of January 31st 1953

A preliminary investigation of the damage caused by the catastrophic gale of January 31st 1953 indicated that in winds of such intensity, all species over 45 feet in height were susceptible to windblow, though spruce on firm ground tended to be broken off instead of uprooted. Oak and sycamore were the two apparently most windfirm species. Scots pine, the commonest species, suffered badly. Edges of plantations often withstood the gale, and recently thinned crops were the most susceptible to blow. Further data is being collected.

Silvicultural Experimental work on Poplars

Work on poplars was continued and expanded. The benefits of mulching or mounding round the plants at the time of planting were confirmed, and good responses were obtained to applications of nitrogen fertilizers. Striking improvements in growth and leaf colour were obtained by applying lime on acid soils. Cuttings raised at wide and close spacings in the nursery, when planted in the forest, grew equally well. Experiments have been started to determine to what extent deaths in the year of planting may be due to drying out of the roots after lifting in the nursery, and further studies on liming and nitrogen manuring are being carried out. A special study is being made of the best age and type of plant of the aspen hybrid, *P. tremula* x *tremuloides*, to use, as this species has proved difficult to establish by normal planting

methods. Long term spacing experiments have also been laid down. A considerable programme of nursery experiments has also been undertaken.

Varietal Trials and other General Work on Poplars

Eight major, and eleven minor poplar varietal trial areas have now been started in Great Britain, but most of them are still too young to have produced results. However, the trial at Yardley in Northamptonshire has been assessed. It is encouraging that some of the plots in this trial, which was planted on a site hardly suited to poplar, are closing canopy and starting to suppress the coppice.

The varietal collection now contains 260 clones, some of which are only of botanical interest.

Twenty-five acres of land have been procured for use as a National Populetum and a start has been made with planting. Most of the land, however, will not be ready for use till the winter of 1953-54.

Visits were made to Italy in connection with the sixth session of the International Poplar Commission, and also to Northern Ireland.

Over 33,000 cuttings of standard varieties for general planting, and about 700 cuttings of other varieties for experimental use, were distributed to outside persons and institutions during the year.

Forest Genetics

The survey of seed sources and the selection of parents for future breeding work continued during the year. Over one hundred woodlands were classified for seed collection purposes in the North Conservancy of Scotland. The total area of "plus" and "normal" stands in that Conservancy amounts to 1,500 acres. The survey proceeds at the rate of one Conservancy each year.

More than two hundred 'plus' trees were selected during the survey of seed sources. The total of 'plus' trees for all species in common use is now six hundred and twenty-four. The propagation of these trees by grafting and by rooting of cuttings continued during the year, with the objects of preserving the best pheno-types and collecting them together into a convenient place.

The gale of January 31st, 1953, in North-east Scotland blew down one hundred and forty-seven 'plus' trees, mostly Scots pine. These have been preserved by collecting material and grafting it, involving about 7,500 grafts.

Four years of work on the rooting of dormant and summerwood cuttings is summarised and the future lines of work are indicated. The importance of the origin of the cuttings is stressed. The ability to develop roots varies among other things with the species and age of tree, and the position of the cuttings on the parent tree. Cuttings from mature trees of Scots pine, Corsican pine and oak, ash, beech, etc., are difficult subjects at present. Experiments have shown that dipping the cuttings in a solution of 1 mg. of indolyl-butyric acid in 1 cc. of fifty per cent alcohol gives good results. The best conditions of soil temperature, air temperature, humidity and light for rooting cuttings are being investigated, and include sub-irrigation methods in replacement of overhead watering. Vermiculite and granulated peat, either alone or in mixture, have proved to be the best media so far tested for striking cuttings.

The general study of flowering and fruit production has been continued. Evidence is accumulating of a correlation between a good seed year in some species and warmer, dryer, and sunnier-than-average weather during the summer *before* the flowers appear. The correlation is good in Corsican pine, but in

larch and beech it is often modified by spring frost damage to the flowers, which can greatly reduce the seed crops.

The report by species includes information about the planting of progeny trials of beech and Sitka spruce; about progress of the establishment of three experimental seed orchards in Scotland for the production of first generation hybrid larch, and of the planting of experimental seed orchards of Corsican pine and beech at Rendlesham, Suffolk. A new trial of methods of inducing cone production in Corsican pine has been commenced in Clipstone Forest, Nottinghamshire.

Studies of Growth and Yield

Sixty-nine new permanent sample plots were established, 50 in coniferous and 19 in broadleaved species. The yield tables for conifers were revised and a general volume table for small hardwoods, not catered for in the published tables, was prepared. The report on the census of hedgerow and park timber and of woods under five acres was completed and a start was made on census revision. It is planned to resurvey a few counties each year in rather greater detail than was possible in the last census. Other work included the design and analysis of experiments, lectures and field demonstrations.

Forest Pathology

The work of the Pathological Section is dealt with under the heading 'The Control and Avoidance of Forest Tree Diseases', which incidentally presents a review of most of the work completed or in progress.

The diseases are dealt with according to the methods of control or avoidance to be adopted. Under 'Quarantine Measures' the danger of the introduction of Chestnut Blight, Oak Wilt and Elm Phloem Necrosis, all so far happily absent from this country, and the means to be taken to prevent their entry, are discussed. Under the same head, the possiblity of control of tree diseases by eradication is discussed with especial reference to Elm Disease, and Sooty Bark Disease of sycamore.

Under 'Choice of Site', the incompleteness of our knowledge of site values in relation to tree disease is stressed. This makes avoidance of disease by choice of site a very chancy business. An attempt to find sites for *Pinus strobus* isolated from current bushes, which are the alternate host of the dangerous White Pine Blister Rust, is also mentioned.

'Choice of Variety', leads to a discussion of varietal and clonal selection for disease avoidance. Apart from the testing of poplar for resistance to bacterial canker, which is dealt with at some length, work on clonal resistance is still in the very early stages.

'Adaptation of Silvicultural Practices' is obviously an attractive means of control on account of the low cost, as compared with special operations designed for control alone. In a number of instances, such as use of young poplar planting stock, or early pruning of older plants, to avoid infection with *Dothichiza populea*, it has been possible to make recommendations on these lines. Considerable knowledge of the relationship between the pathogen and the tree is required, however, before a practical method can be elaborated, and with many of our forest diseases this knowledge is still lacking.

'Adaptation of Nursery Practices' tends to be rather easier, for nursery disease investigations can often be completed in a much shorter time. Under this heading the autumn dieback of young conifers caused by *Botrytis*, which

is proving hard to control, and the possibility of avoiding attacks of *Keithia thujina* by growing *Thuja* in isolated nurseries, are discussed.

'Treatment with Chemicals' is of course an orthodox method of control in agriculture and horticulture. In forestry it is practically confined to the nursery, and even there certain diseases such as *Keithia thujina* and *Botrytis cinerea* have proved difficult to deal with in this way. Work on the chemical dusting of coniferous seed, using chiefly tetra-methyl-thiuram-disulphide, is described.

Wound protection is not generally required in forest practice, but the possibilities of pruning decay-susceptible trees such as beech, and of increased attention to roadside trees, which inevitably require some pruning, make experiments on wound protectants desirable. An experiment, using mainly various bituminous paints, has been started on pruned beech and lime.

Under the heading 'Difficulties of Control' various diseases are discussed, means for the avoidance or control of which are still undiscovered. In most cases this is because our understanding of the disease as a whole is still insufficient. The most important diseases dealt with here are Top-dying of Norway spruce, Group-dying of Sitka spruce, and Bark Dieback of beech.

Forest Entomology

The survey of sawflies in spruce and larch crops was carried out as in previous seasons and expanded to include a further fifteen forests in east and south Scotland. No major infestation of any of the thirteen species under review was located, and the data collected on population density showed that the 1952 levels were about the same as those in 1951. The laboratory studies on this group were expanded and intensified. The gradual accumulation of morphological and biological data continued, and one major taxonomic point elucidated by the discovery that the species previously referred to in these reports as *Anoplonyx duplex* Lep., is in fact, a hitherto undescribed one to which the name *Anoplonyx destructor* Benson has been given.

A survey of forest insect conditions in the pine areas of East Anglia was initiated, and work in the first season was concentrated mainly on an investigation into the status of *Bupalus piniarius*, the Pine Looper Moth, and on a review of the bark beetle situation.

Two projects relating to the field use of insecticides were carried out. The first tested the usefulness of benzene hexachloride, dieldrin, DNOC, lindane, and lindane/toxaphene when applied to normal billet and spray traps for the control of pine weevil. Initial results were slightly encouraging, but the technique is of doubtful practicability. In the second experiment two systemic insecticides, Pestox 3H and Hannane, were applied to young Douglas fir in an effort to control *Adelges cooleyi*. When applied directly to the foliage, good control was achieved with both insecticides for a period of six weeks; but application by watering on to the roots was ineffective.

A series of sample plots to study population variations of *Neomyzaphis abietina* in approximately 20-year-old Sitka spruce crops, and the effect of these variations on the rate of growth of the crops, was laid down; and the first of the five planned annual assessments carried out.

A general reconnaissance of the Scottish gale damage areas, where both beetle and weevil outbreaks on a large scale can be expected, was undertaken, and plans made for future work on these problems.

Machinery Research

British Tractors. A wide range of British tractors is now available, and attention is at present directed to operation on soft ground at an economic cost.

Ploughing. Progress is being made in the development of mounted implements on tracked tractors.

Haulage over soft ground. The value of large diameter wheels for use on soft forest rides has been established.

Fire protection. Modifications have improved the performance of the standard fire pump.

Cableways. A Swiss cableway has been imported for trial.

Road haulage. The commercial tendency to use vehicles of greater payload is being followed.

Nursery cultivation. Lining out and spraying machines are being investigated.

Drainage. A machine is being developed for cleaning drains in plantations.

Utilisation Development

The Advisory Committee on the Utilisation of Home-Grown Timber continued to devote its attention to problems affecting the utilisation of small-sized conifer and hardwood thinnings, coppice, scrub and waste timber.

The market for small-sized unbarked coniferous thinnings for a certain type of paper manufacture was investigated, but it was found that the demand was not likely to be as large nor as permanent as had been indicated earlier.

Over 70 Scottish firms engaged either wholly or part-time on wood turning were visited during the year. Their current consumption of home-grown hardwoods was estimated at half-a-million hoppus feet per annum, principally beech and sycamore.

The Rural Industries Bureau completed their survey of the underwood industry during the year. Preliminary figures for hazel have been worked out, and show that only a small fraction of the total area of hazel is at present being utilized. Printing-paper was made from whole unbarked shoots of hazel on a laboratory scale by the British Paper and Board Industry Research Association. Field work on the yield of chestnut coppice was completed by the end of the year, using the methods previously applied to hazel coppice.

The use of waste timber for the manufacture of building boards on a small scale in Germany was studied, and the home manufacture of wood-flour from waste was investigated fully.

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

Nutrition Problems in Forest Nurseries

Work on this major project has been going on since 1945 under the general direction of a Sub-Committee (of the Research Advisory Committee) on Nutrition Problems in Forest Nurseries. Dr. E. M. Crowther and Miss Benzian of Rothamsted Experimental Station, report on the 1952 experiments.

One of the main subjects investigated is the relative merit of organic dressings, either composted or plain, and chemical fertilizers as a means of maintaining fertility. An experiment on an acid nursery at Bagley Wood near Oxford, compared repeated dressings over five years of six composts (with and without addition of inorganic fertilisers) with three uncomposted organic materials, and inorganic fertilizers. The inorganic fertilizers gave as good, and often better, results than those obtained with the organic composts, provided care was taken to correct any magnesium deficiency. This is rather remarkable when it is considered that some of the composts contained three to five times as much nitrogen, and two to three times as much phosphorus or potassium as was given in the single-rate inorganic fertilizers.

The role of green crops and leys in maintaining nursery fertility is being investigated in a series of crop rotation experiments. Preliminary experiments at Kennington near Oxford and at Wareham (Dorset) with yellow lupins, rye, perennial ryegrass, S.100 white clover, compared with fallow, and with continuous cropping with Sitka spruce, showed negligible effects from the green crops. The best first-year crops of Sitka were after bare fallow. The experiment failed to provide any support for the common view that the maintenance of soil fertility in forest nurseries depends on the addition of organic matter either by green-cropping or manuring. Two new series of rotation experiments designed to last for a longer time have been laid down to test these matters further.

In experiments with various seedbed covering materials, most of them used in normal Conservancy nursery practice, it was found that a healthy heathland nursery could be reduced to the state of a poor established nursery on agricultural land, in four years, by the use of covers containing limestone.

Experiments on growing conifer seedlings on soils with wide range of soil reaction from acid to neutral or slightly alkaline showed in general the poorest growth towards the alkaline end of the range. The superiority of ammonium sulphate, an acidifying form of nitrogen fertilizer, over "Nitrochalk" on neutral or slightly acid soils, was confirmed.

In experiments to test the effects of formalin followed by either compost of fertilizer dressings, in 5 nurseries, formalin increased the number of usable plants, the formalin-plus-fertiliser giving a greater improvement than formalin-plus-composts. In another experiment, winter applications of formalin gave better results than spring applications, especially for the heavier rates. Tests with chloropicrin as a sterilising agent gave results equal to or sometimes superior to formalin. It is the only chemical tested that has approached formalin in effectiveness. Application of formalin to transplant beds increased the height of plants by 2 to 3 inches, but it must be done early in the season, well before the plants have been set out in the beds. Delaying application until only one month before lining out killed most of the transplants, in one experiment.

A manuring experiment on transplant lines at Wareham, with repeated dressings of nitrogen, phosphorus, and potassium annually since 1949, showed small increases in rate of growth, but striking effects on form and colour. In years when general growth was good, the effect of nitrogen fertilizers was particularly large.

Several series of planting experiments in the forest to determine the residual effects of nursery treatments, and to test the usefulness of fertilizers at the time of planting, have been laid down over the last few years. In general, the previous nursery treatment effects are small or negligible. The response to fertilizers in the forest is very variable, being nil in some forests, particularly grassland types, and giving an increase of 25 to 50 per cent in height in one year on certain other sites, notably at Broxa, Langdale Forest (E. Yorkshire).

Investigations on Partial Sterilization of Soil for Disease Control

Dr. S. D. Garret reports on the development of investigations started by Dr. J. H. Warcup who found that in soil partially sterilized by formalin, the fungus, *Trichoderma viride*, became dominant for a year and a half or more after treatment. *Pythium ultimum* and other tree seedling pathogens were killed by formalin. It was suspected that the known antibiotic effect of *T. viride* might be a controlling factor keeping down *Pythium ultimum*, but critical experiments showed the reverse to be the case. The possibility of formalin and of the antibiotic action of *T. viride* killing certain gram-positive bacteria which are known to control *Pythium* is discussed.

Researches in Soil Mycology

Researches by Dr. Ida Levisohn were mainly concerned with the rhizosphere effect of mycorrhizal mycelia. Earlier experiments had shown that dichotomous branching of actively growing short roots of Scots pine can be induced by exudates from mycorrhizal fungi. The special method whereby this was demonstrated, was successfully applied to a number of other pine species and other mycorrhizal fungi.

Watering of pot-cultures of pines with sterilized leachings from various soils failed to produce any root forking.

It was established that ectotrophic mycelia can stimulate the growth of endotrophic tree seedlings, although unable to form root associations with them. The converse relationship does not hold.

The Effect of Tree Growth on Soil Profile Development

The results of the work at Culbin Forest, Morayshire, by T. W. Wright of the Macaulay Institute, Aberdeen, may be summarised as follows:—

Mechanical analysis. No evidence has been found that tree growth is having any direct effect on the mechanical composition of the soil except by the incorporation of organic matter into the upper layers, which appears to occur more readily under Corsican than under Scots pine.

Moisture studies. Readings from gypsum moisture blocks and the 'Speedy' moisture tester show that moisture deficiency during the growing season occurs at rooting depth under all species and age classes of trees studied, being most acute before the closure of canopy. Unplanted dunes do not dry out, and soil moisture in the planted areas is increased by heavy thinning. Thatch is efficient in reducing surface evaporation.

Chemical analysis. Trees and ground vegetation are shown to remove nutrients from the lower soil horizons and to return a proportion to the surface as litter. Phosphate content of the soil is extremely low, and a small phosphate manuring trial is suggested. Ammonification increases with the age of the crop.

Other work. An experimental moisture tester of the slow neutron type is being used with success.

Growth and Nutrition of Spruce and Pine in Heathland Plantations

Dr. Leyton concludes, from four years experimental work, that nitrogen deficiency is the most important nutritional factor limiting the growth of spruce, and that by heather mulching this can be relieved. On these heathland sites, addition of phosphate fertilizers only produces a response if nitrogen is also available. Pines behave similarly but to a much smaller degree. It is

found that the concentration of nitrogen in the current year's needles of spruce is closely correlated with that in the heather foliage, a point that may be of some value for assessing the potentialities of a heathland site for the growth of spruce.

The Forest Ecology of Acid Soils

Dr. Dimbleby discusses the approach to studying heathland sites, particularly with reference to the effects of long term forestry operations, and stresses the importance of historical researches (pollen analysis has proved of value here), and observations of the influences of different species and mixtures to-day on soil processes. For the latter, some 40 species of hardwoods have been raised on Broxa Moor (Langdale Forest, E. Yorkshire), many of which it is hoped to establish as tree crops.

Physical and Chemical Properties of Forest Soils.

Mr. Rennie reports on soil studies in an old pine wood on heathland in Allerston Forest, and under various other broadleaved species in the same area, as well as under open *Calluna*. The observations may give some indication of the changes that may take place under afforested heathland (unploughed).

In some studies of soil phosphorus, both as "total P", and "easily soluble P", on podzolic moorland soil and on alluvial valley soil, it was found that, while the total amounts of phosphorus in each were similar, the distribution was very different, being fairly uniform down to 50 cms. in the valley soil, but very variable in the podzol profile. The proportions of easily soluble P varied very greatly in the different layers of the podzol profile.

Soil Faunal Investigations

Mr. P. W. Murphy, working at Rothamsted, has added greatly to our knowledge of the meso- or meio-fauna of forest soils. No less than 53 different species of Acarina have been extracted from heathland soils, and a good idea of the relative numbers of the more important species, and their distribution in the soil, has been obtained. The list includes two new species, two new British records of genera, and five new specific records. The distribution of the mites in relation to pore space and soil moisture is discussed, and the conclusion reached that water content and possibly lack of oxygen are effective barriers limiting the fauna to a narrow surface and subsurface zone of the raw humus. High populations of particular species are found in the humus 'sandwich' resulting from ploughing.

Experiments are in progress to ascertain the preferences of the more important species for different types of litter, and to try and get some quantitative estimate of the amounts of litter consumed. A full account of Mr. Murphy's work is published in the *Journal of Soil Science*, 4 (2) July 1953, pp. 155-193.

Studies on the Relationship between Larch Canker and Trichoscyphella willkommii

Dr. J. G. Manners reports investigations into the biology of this fungus, its culture and nutritive requirements, and the results of inoculation experiments on larch trees. It is found that 18 months may elapse between inoculation and the appearance of an obvious canker, and that Scottish strains of European larch are more resistant to inoculation than those of Swiss origin. The relationship between bark freezing, infection with the fungus and canker formation is being investigated.

Investigations into the Biology of Cryptostroma corticale and the Sooty Bark Disease of Sycamore

Work on the Sooty Bark disease of sycamore carried out by J. A. Townrow at the Botany School, Cambridge, had been mainly directed to finding the conditions and means of infection. The spores are very sensitive to changes in temperature and relative humidity, and can only infect fresh wounds.

It has been found that a staining of the wood is regularly associated with infection by *Cryptostroma*, but as this is also frequently found in trees from which *Cryptostroma* is absent, it may be due to secondary organisms. *Cryptostroma* can be isolated from well outside the stained area.

The fungus has been isolated from roots, but it appears likely that it spreads down from the aerial portions of the tree to the roots, and that the roots are not therefore the initial site of infection.

Inoculations of saplings are being carried out at intervals, but it is too early yet to expect any results.

Biological Investigations on Megastigmus Insects Infesting Conifer Seed

Mr. N. W. Hussey of the Department of Forest Zoology, University of Edinburgh, has concluded his studies on *Megastigmus*. Notes are presented on the biology of *Amblymerus apicalis*, the main parasite of *Megastigmus*, together with some conclusions gained from the field investigations. Extensive study of the diapause problem in the laboratory suggests that prolonged rest is genetically fixed in a small percentage of the population, but a further percentage can be influenced by weather conditions in the spring.

Botanical Studies of Variation in Certain Conifer Species

These were continued by Dr. E. V. Laing on larch, Douglas fir and *Pinus contorta*, and diagnostic botanical differences between variants of each of these species are described.

European larch seedlings vary in their cotyledon structure. In *Pseudotsuga* more work has been done on trees which are intermediate between Green and Blue Douglas. In *Pinus contorta* (agg.) there are two distinct trees in our plantations differing in size of buds, leaves, bark, cones, seed, seedlings and timber.

Part I. Work carried out by Forestry Commission Staff.

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES
Assistant Silviculturist
and G. Buscewicz

As in previous years, the work of the seed laboratory at Alice Holt was divided between routine testing of seed quality, and research work on problems of seed collection, extraction, storage, and testing. Routine purity and germination tests are carried out during the seven months between October and April, in which period there is little time for experimental work. In 1952-3, 640 germinator tests and 135 chemical viability tests were completed on samples received from Commission Seed Stores. Chemical viability tests were applied only to late arriving samples on which a test result could not be issued, using normal methods, in time for seed sowing.

Germination Test Methods

Examination of the triphenyl tetrazolium bromide embryo-staining technique for rapid estimation of seed viability, was continued. This investigation was part of the series of experiments started in 1949, to assess the relationship between test results by standard germinator methods, the tetrazolium staining technique, and actual field germination over a wide range of nursery conditions.

Since 1949, over one million seeds, of seven conifer species, have been examined, but progress has been slow owing to the large amount of data required to permit reliable comparison of test methods. Analysis of available data is almost complete and will be available for publication shortly. For common conifer species, the tetrazolium test is equal in reliability to normal germinator methods as a means of assessing seed germination capacity. The main comparisons have been made with the Copenhagen tank germinator, and it is evident that, providing a standard test procedure is followed, there is a highly significant correlation between the results of the two methods. This statement is true for Sitka and Norway spruce, Corsican pine, Scots pine, European larch, and Douglas fir. Results with Japanese larch have been less satisfactory. It seems that a revised scheme of classification of embryo-staining categories after tetrazolium treatment may be necessary for this species.

Estimation of nursery germination from laboratory test results is a more difficult problem owing to the multitude of uncontrolled factors influencing germination under field conditions. Test results undoubtedly provide a useful index of likely field performance of a seed lot, but results can be forecast only within broad limits. Attributes other than germination capacity have been found to be important in determining field germination. For instance, determination of seed size, and germination energy or speed of germination, assist in forecasting the sensitivity of seeds to adverse conditions such as drought, during the germination period in the field.

Testing germination of Douglas fir and Sitka spruce is often troublesome as both species are slow germinating, frequently requiring 40 to 70 days for completion of a laboratory germinator test. Profuse growth of moulds on the seeds after about 30 days in the germinator interferes with the progress of the test, and the normal procedure has been to stop the test at this point and examine ungerminated seeds with tetrazolium. This technique is unsatisfactory, and time-consuming, as the numbers of ungerminated seeds remaining at the end of the test is often as high as 30% of the seeds sown. Examination of methods of seed treatment to speed up germination has resulted in the adoption of a prechilling treatment before all routine tests for these species.

It was found that chilling the seeds on moist blotters for 21 days at 36°F. resulted in germination of 90% of germinable seeds after 14 days in the germinator, untreated seeds requiring 40 to 50 days on the germinator to reach this value. Soaking the seeds in water at 36°F. had similar but less pronounced effects, while soaking at room temperature had little effect and in some cases was damaging.

Seed-Borne Fungi

The work on seed-borne fungi reported in *Report on Forest Research*, 1952, was continued with the assistance of Dr. S. Batko of the Pathology section. The object of the investigation has been to identify the fungi carried by tree seeds, and to assess their influence, if any, on seed germination and seedling development.

A large number of the fungi occurring on coniferous seeds has been identified, and many have been isolated in pure culture. The practical significance of the species isolated is not known, but it is proposed to carry out inoculation trials on surface-sterilized seeds in a first attempt to assess the importance of individual species of fungi on the progress of germination. The main species of fungi isolated from seeds under test are as follows:

1. Very common: *Penicillium* spp.,
   Oedocephalum glomerulosum,
   Chaetomium globosum,
   Stachybotris atra
2. Common: *Ascophamus carneus*,
   Aspergillus niger,
   Rhizopus nigricans,
   Trichothecium roseum
3. Uncommon: *Botrytis cinerea*,
   Alternaria spp.
   Cylindrocarpon spp.
   Fusarium spp.
   Mucor mucedo,
   Stemphilium spp.
   Verticillium spp.
4. Rare: *Epicoccum*, *Oospora*, *Stysanus*.

The growth of fungi during germination tests still constitutes a serious practical problem in tree seed testing. Dressing seeds with fungicide dusts has proved unsatisfactory in practice, as all materials used slow down seed germination to some extent. The only method of dealing with this problem at present is to raise the standard of laboratory hygiene coupled with application of appropriate seed pretreatments to increase the speed of germination.

Seed Storage

Longevity of Oak and Beech Seeds. In continuation of the study of seed storage for these species, seeds which had been exposed to a variety of storage conditions since autumn 1950 were tested for germination. In the case of oak, the results of chemical viability tests on seeds stored for eighteen months were found to be misleading. A more accurate assessment was obtained from actual germination of samples in autumn 1952, two years after the seeds were placed in store. (See Table 1.)

GERMINATION TESTS ON ACORNS STORED FOR TWO YEARS

Table 1

	Tests After Two Year Storage	
	Moisture Content, % (on dry wt.)	Germination Capacity, %
Moist sand, 36°F.	174	67
Moist peat, 36°F.	130	80
Dry peat, 36°F.	86	73

Initial moisture content=85% on dry wt.
Initial germination capacity=95%.

All other storage treatments failed. Storage in sealed containers and storage at temperatures below freezing point were fatal; similarly, reducing the seed moisture content below 70% (dry weight) had fatal results. A new trial was commenced in Autumn 1952 to examine the best treatments in more detail.

Attempts to store beechmast for periods longer than eighteen months failed completely. Further trials will be carried out to investigate seed moisture content and methods of seed drying before storage.

Longevity of Birch Seeds. It has been found that birch seed, stored for longer than the winter following collection, has given variable results. In view of this, a small experiment was started in 1950 comparing several methods of storage and the results are summarised in Table 2.

GERMINATION OF BIRCH (BETULA VERRUCOSA. EHR.) AFTER STORAGE FOR ONE AND TWO YEARS

Table 2

Storage Method	Unheated Room		Constant 36°F.		Constant 25°F.	
	One Year	Two Years	One Year	Two Years	One Year	Two Years
Dry, sealed....	21	20	20	21	19	20
Moist peat, sealed	Nil	—	Nil	—	21	17

Initial germination capacity=27%.

There is no difficulty in storing birch seed for periods of at least two years if the seeds are placed dry in sealed containers. If this is done, storage temperature within the limits tested appears to have no appreciable effect for seeds

stored up to two years. Stratification of seeds in moist peat failed, except at a storage temperature below freezing point when the moisture in the storage medium would be unavailable to the seeds.

Longevity of Conifer Seeds. The long term storage trial, started in 1950 with seeds of common larch, and pine and spruce species, was continued into its third year. Tests on samples in 1952 confirmed that prolonged unsealed storage at temperatures above freezing point is damaging for all species. Germination values of samples taken in 1952 showed a sharp drop below those obtained in 1951 on samples from the same seed lots.

In general it appears that storage in sealed containers is essential; also that seed moisture content and storage temperature is of great importance in determining the period for which seeds can be stored without loss of visibility. For most species the moisture content should be just below 10% of dry weight. If the moisture content exceeds this appreciably, deterioration of seeds may begin within one year of sealing the containers. This is most marked for seed stored sealed, in rooms without refrigeration. Deterioration appears to be much slower if the seed is kept at a constant temperature of 36°F.

A series of experiments is now under way to examine in more detail the importance of seed moisture content in the storage of conifer seeds.

EXPERIMENTAL WORK IN NURSERIES

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

Partial Sterilization of the Soil

Steaming Methods

The large scale steaming experiment first conducted at Newton, Moray, in 1951 was repeated in early March, 1952 at Fleet Nursery, Kirkcudbrightshire. The 'canopy' or hood system was employed to sterilise an area of 50 ft. x 3 ft. in one operation. Two steaming treatments were compared, namely, steaming for 20 minutes, and steaming for 30 minutes. In both treatments the steam pressure at the inlet manifold to the apparatus was maintained at approximately 20 lb. per square inch during the period of steaming. Treated areas were sown with Sitka spruce and the results of the experiment are given in Table 3.

EFFECT OF TWO PERIODS OF STEAMING ON WEEDING TIMES AND THE MEAN HEIGHTS AND NUMBERS PER SQUARE FOOT OF ONE YEAR SITKA SPRUCE SEEDLINGS

Table 3

Treatment	Mean Ht. in ins.	Nos. per sq. ft.	Weeding times as minutes per sq. yd.
Control (No steam treatment)	1.3	47.8	88.5
30 minutes steam treatment	1.9	41.2	18.1
20 minute steam treatment	2.0	45.4	23.1
Standard Error	±0.1	—	± 4.6
Significant Difference at 5% l.	0.3	Not	13.8
„ „ at 1% l.	0.4	significant	19.1

The results obtained are comparable with the results at Newton in 1951, although height growth responses were not so impressive. Mean heights of seedlings for both levels of steaming were significantly greater than the control, the number of seedlings was not significantly affected, and weeding times were greatly reduced. It should be noted that the soil at Fleet is much heavier than the Newton soil, and because of this the soil temperatures at a six inch depth did not rise to 180°F. even during the 30 minute treatment. Before treatment the soil temperatures at a depth of 6 inches was 39°F., and this rose to 60°F., 82°F., 120°F, and 160°F. at depths of six, five, four and three inches respectively.

This experiment confirmed that areas of up to 150 square feet can be treated successfully in one operation by using the hood system, compared with the 60 square feet attained with the normal Hoddesdon grid.

This experiment brings to a close eight seasons work on the partial steam sterilisation of open air nursery seedbeds. Steam has proved to be more effective as a soil sterilizer than a selection of some half dozen chemicals tested; it increases the size and vigour of the seedlings without decreasing their number and also has proved to be more effective as a weedkiller than the chemical sterilizers.

The most efficient system of applying the steam to the ground is considered to be the hood or canopy system. This obviates the slow and cumbersome Hoddesdon method of digging long pipes into the ground, which can only be done when soil conditions are very good. The hood system confines the steaming to the actual seedbed area and a much larger area can be treated at one time. Although the soil is not sterilized to so great a depth, equally good results are obtained judging by seedling response.

Nevertheless, the use of a large steam boiler involves great difficulties in practical application, and even with the hood it is expensive to operate. Because of this it is considered that chemicals, and in particular formalin, are more suitable for treating "soil sickness" in nurseries which have been cropped continuously for many years.

Sterilization with 'D-D' Soil Fumigant

Work was conducted for the third year at: Fleet, Kirkcudbrightshire; Newton, Moray; Inchnacardoch, Inverness-shire; and Benmore, Argyll, to test the efficiency of Shell 'D-D' soil fumigant as a soil sterilizing agent for seed beds in comparison with formalin. Two concentrations of 'D-D' were used (300 lb. and 450 lb. per acre) and these were injected into the soil at a depth of four inches, using injector points spaced at fourteen inches apart. Twenty-four hours after application, half the plots were forked to a depth of five inches with the object of obtaining a better distribution of 'D-D' within the top soil. Formalin treated plots were treated with 0.05 galls. of commercial formalin diluted with 1 to 2 gallons of water per square yard. Two weeks later all plots were cultivated to a depth of four inches in order to work up the normal seedbed tilth and to permit residual vapours to escape.

Germination assessments during June and July showed that while the 'D-D' treatments at Newton, Benmore and Fleet had not affected germination, at Inchnacardoch in the early stages of germination both concentrations of 'D-D' significantly retarded germination, and formalin had a similar but more pronounced effect. By early July however all treatments had approximately the same number of seedlings, and differences were no longer significant.

Formalin produced the greatest mean height responses at all nurseries except Newton. At Benmore and Inchnacardoch the lower concentration of 'D-D' significantly increased mean heights, and the higher concentration of 'D-D'

highly significantly increased mean heights. At Newton and Fleet, 'D-D' produced slightly taller seedlings than untreated ground, but the differences were not significant. At most nurseries, cultivating the soil twenty-four hours after applying 'D-D' increased the mean heights of seedlings very slightly, but only at Newton was the increase significant.

Neither the sterilization treatments nor the subsequent cultivation produced any significant differences in numbers of seedlings. Weeding times were not significantly decreased by applications of 'D-D', which in general were well in excess of the weeding times on formalin treated ground.

During the past three years, experiments using 'D-D' as a soil sterilizing agent for conifer seedbeds have shown little evidence that the material has practical value as a sterilizing agent, and accordingly no further experiments are contemplated.

Residual Effects on Second Year Sowings on Soils Treated with 'D-D' Soil Fumigant

The 1951 experiment at Newton, Benmore and Fleet, in which 'D-D' was applied at rates of 150 lb., 300 lb. and 600 lb. per acre, and compared with formalin, was re-sown without further treatment. The resulting crops of seedlings on 'D-D' treated soil were smaller than seedlings grown on formalin treated ground, and only at Fleet were plants on the 'D-D' treated plots taller than the plants grown on unsterilized plots. Neither 'D-D' nor formalin had any significant residual effect on either the yield of seedlings or the weeding times.

These results confirm that 'D-D' soil fumigant shows little promise of proving an efficient soil sterilizing agent for conifer nursery seedbeds.

Formalin Sterilization—Large-scale User Trials

A series of replicated trials was carried out in 1952 in 12 established nurseries in England and Wales, with the object of assessing the response of conifer seedlings to standard formalin treatment on sites of differing soil type and cropping history.

The standard treatment applied corresponded with the best treatment tested in experiments in previous years, and involved application of 0.05 gallons commercial (38 per cent) formalin in $\frac{1}{2}$-$1\frac{1}{2}$ gallons of water per square yard of seedbed at least three weeks prior to seed sowing. In all cases full fertilizer dressings were applied before formalin treatment.

Scots pine, Norway spruce, Sitka spruce and Douglas fir were sown as test species in ten nurseries, while Corsican pine and lodgepole pine were sown in subsidiary trials in the remaining two nurseries.

In the main trials, formalin had no effect on total seedling production, except for a slight reduction in seedling numbers of Norway spruce in one nursery and Sitka spruce in another. Formalin improved the height growth of seedlings in only three nurseries out of the ten treated. The growth of Scots pine, Norway spruce and Sitka spruce was improved at Delamere (Cheshire), and Tunstall (Suffolk), and that of Norway spruce, Sitka spruce and Douglas fir, at Mortimer Nursery (Hereford). In all these cases the growth improvement was substantial. The ineffectiveness of formalin in the remaining six nurseries was unexpected in view of the success which has normally attended this treatment on the majority of soil types on which it had been tested experimentally. The soils which were concerned in the 1952 trial differ widely in acidity, texture and cropping history, but it has not been possible to associate success or failure of formalin treatment with any particular set of soil characteristics or with the methods of application in individual nurseries. These trials are to be repeated in 1953. The growth of one-year

seedlings of Corsican and lodgepole pine was increased considerably after formalin treatment in two comparatively new nurseries on very sandy soils in Wales. This result is of interest as pines are the least responsive of the common conifers, and the soils are quite unlike the heavily cropped loams in older nurseries which have given the best responses in the past.

Formalin Powder Sterilization

A trial was laid down in 1951 at Fleet and Newton to compare formalin powder (15 parts 38% formalin to 85 parts of a mixture of Kaolin 1 part and Kieselguhr 2 parts) at rates equivalent to 0.02, 0.06 and 0.1 gallons of 38% formalin per square yard, with the standard solution of 0.1 gallon of 38% formalin in 1¼ gallons of water. At Fleet, the dry applications in the mineral carrier equivalent to 0.06 and 0.1 concentration of formalin produced a better sterilizing effect than formalin solution. At Newton formalin powder at all concentrations produced smaller plants than the liquid formalin.

Chloropicrin Sterilization

A trial was laid down at the Royal Botanic Garden, Edinburgh, to determine whether chloropicrin injected into the soil two weeks before sowing and at three rates of application would prove a suitable soil sterilizing agent. Unfortunately the Sitka spruce seedlings on the treated beds were severely attacked later in the season by 'cutworms', (*Agrotis* spp.) and an assessment of heights and numbers was not carried out.

The chemical proved much easier to apply than had been anticipated, and a more critical series of experiments was started in spring 1953.

Manuring

Placement of Fertilizers

The final experiment of a series on the placement of fertilizers was carried out at Tulliallan, Fife; Widehaugh, Northumberland; Broxa Moor, Yorkshire; Newton, Inchnacardoch and Fleet. These experiments compared broadcast sowings of Sitka spruce seed, at two densities, on plots treated with broadcast fertilizers, with equivalent rates of band sown seed, sown over phosphate and potash fertilizers drilled at a depth of one inch.

At the end of the season it was evident that fertilizers placed below the band sown seed increased the mean heights of the spruce seedlings at all nurseries, but in general a reduced yield of seedlings resulted. Comparisons between the broadcast and band sown treatments are given in Table 4.

MEAN HEIGHTS AND YIELDS OF SITKA SPRUCE SEEDLINGS PER POUND OF SEED OBTAINED FROM BROADCAST SEED OVER BROADCAST FERTILIZERS AND BAND SOWN SEED OVER PLACED FERTILIZERS. SEED SOWN AT TWO DENSITIES

Table 4

	Mean Heights in inches					Yield of seedlings per pound of seed (in thousands)				
Method of sowing and no. of sq. yds. sown per lb. of seed	B'cast 115	B'cast 85*	Band 115*A	Band 85B	Standard Error ±	B'cast 115	B'cast 85*	Band 115*A	Band 85B	Standard Error ±
Nursery:—										
Newton	0.85	0.86	0.89	0.99	0.03	65.2	58.4	54.9	49.3	2.5
Inchnacardoch	1.54	1.51	1.90	1.91	0.06	80.8	83.6	52.9	50.4	2.5
Fleet	2.60	2.70	3.00	3.10	0.04	71.4	69.5	69.4	61.3	3.4
Tulliallan	1.33	1.44	1.85	1.87	0.04	59.8	54.3	65.9	59.8	3.0
Widehaugh	0.57	0.65	0.79	0.75	0.06	72.5	13.2	16.8	14.7	1.5
Broxa	1.57	1.41	1.54	1.44	0.04	73.4	69.2	48.4	41.3	4.0

*Forestry Commission Standard rates.

A=Seed sown in 7 bands 5 in. apart. B=Seed sown in 9 bands 4 in. apart.

These experiments conclude five seasons work on the use of placed phosphate and potash fertilizers as a means of increasing the mean heights of seedlings. Results have confirmed that Sitka spruce seedlings respond very greatly in height at most nurseries to phosphate manures placed 1-2 inches below the seed. Placed potash manures do not produce any marked increase in height growth in seedlings. Band sowing is complementary to placing fertilizers, but band sowing reduces the yield of seedlings per pound of seed. Consequently the benefit in height growth is offset by a reduction in production. Nurseries in which seed is normally band sown to minimise frost lift will benefit by placing phosphate fertilisers, but in nurseries where broadcast sowing is practised satisfactorily there is no evidence on which to suppose that drill sowing above placed phosphate would prove more economical, on account of the smaller yield of seedlings.

Time of Application of Potash and Phosphate Fertilizers

An experiment to determine the effects of applying fertilizers at different times before sowing was repeated at Quarrywood heathland nursery, Monaughty Forest, Newton, Moray; Wykeham, Allerston Forest, Yorkshire, and at Inchnacardoch, Newton, Tulliallan, Benmore and Fleet. The individual treatments consisted of the application of the standard potash and phosphate dressings sixteen, five, and two weeks before sowing, and on the date of sowing. There were two alternative treatments on the date of sowing, namely, fertilizers applied and cultivated into the soil, and fertilizers applied and left in contact with the seed. It was recorded at four nurseries that fertilizers left in contact with the seed had a marked reducing effect on the speed of germination, but that this was lessened if they were cultivated into the soil. Earlier applications of fertilizers had little or no effect on the rate of germination.

At the end of the growing season it was quite evident that applying fertilizers on the date of sowing irrespective of whether they were cultivated into the soil or not, had produced the smallest seedlings. Applications 2, 5 or 16 weeks before sowing produced seedlings of approximately the same height. Numbers of plants were not significantly affected at any nursery by any of the treatments, although there were indications that they were slightly decreased by fertilizers applied on the date of sowing.

These results indicate that fertilizers should be applied to seedbeds at any time between two and sixteen weeks before sowing rather than at the time of sowing; and also that application even sixteen weeks before sowing does not result in any appreciable loss of fertilizer through leaching.

Time and Method of Applying "Nitrochalk" to Seedbeds

A new experiment was started at Inchnacardoch, Newton, Tulliallan, Benmore, Fleet, Wykeham and Littleburn, Findon Forest, Ross-shire, to compare the effects of equal amounts of Nitrochalk applied at different times and in different ways to Sitka spruce seedbeds. Nitrochalk was applied at a rate of 4¼ cwt. per acre as either (a) one-third dressing before sowing with two subsequent top dressings of one-third each at a variety of dates during June, July or August; or (b) no initial dressing but as two top dressings during June, July or August. Only at Inchnacardoch and Fleet were mean heights significantly increased by treatments in which part of the Nitrochalk was applied before sowing. It was generally noticeable that Nitrochalk applications in August, or in August and June, produced the tallest seedlings, but there were no significant differences. Two top dressings of Nitrochalk in June generally resulted in the smallest seedlings. None of the treatments significantly affected numbers, and in no case did even the August application lead to any frost damage.

From these results it appears that applying Nitrochalk as two top dressings in August, or one in June and one in August, may be slightly more advantageous for promoting height growth than the present system of applying two top dressings in July, although such action might in another year make the plants more susceptible to early frost damage. The experiment is being repeated in 1953 in an effort to obtain more conclusive information.

Organic and Inorganic Manuring in Heathland and Woodland Nurseries

An experiment at Broxa Moor, now in the second year, was designed to ascertain whether initial applications of compost can be replaced by a suitable greencrop, i.e. oats and inorganic fertilizers. The main conclusion drawn at the end of the first growing season was that the effect of a ploughed-in greencrop grown with artificial manures, in comparison with an area treated with compost, was to increase the overall mean heights of Sitka spruce seedlings.

In combination with the standard dressing of phosphate and potash, the compost and greencrop behaved in very different ways. Phosphate and potash at standard rates on greencropped areas, produced seedlings averaging 2.03 inches in height and 117 seedlings per square foot, whereas compost in combination with the fertilizer produced seedlings only 0.78 inches in height at a density of 106 per square foot. The difference between greencrop and compost in the presence of N, P and K was on the average 0.36 inches, the greencropped areas producing the taller plants.

Long-Term Fertility Demonstrations

The Nursery Nutrition Advisory Sub-Committee's demonstration at Teindland woodland nursery, Moray, continued into its third year. Main treatments are artificial fertilizers only, compost only, and combinations of the two. Results in Table 5 show that artificial fertilizers alone are still the most satisfactory and productive treatment.

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

Table 5

Treatment	Sitka spruce			Lodgepole pine		
	Mean Hts. in ins.	Nos. per sq. ft.	Nos. per sq. ft. over 1½ in. tall	Mean Hts. in ins.	Nos. per sq. ft.	Nos. per sq. ft. over 1½ in. tall
No manures or compost	0.32	260	0	0.86	124	40
Artificial fertilizers only	1.51	286	122	1.64	134	80
Compost only	1.00	266	10	1.26	114	20
Artificial fertilizers and compost	1.12	278	42	1.59	117	59
Standard Error ±	0.04	25	—	0.06	7	—
Difference for 5%	0.15	85	—	0.19	23	—
significance 1%	0.23	130	—	0.28	34	—

The fertility maintenance demonstration sections of the original heathland nursery of the late Dr. M. C. Rayner at Wareham, Dorset, continued to be highly productive. A large part of this nursery has been cropped regularly with seedlings and transplants since 1943, using organic manures and composts for fertility maintenance. The crop yields in 1952 showed that there is no apparent decline in fertility as the nursery becomes older.

In recent years, an increasing number of experiments on problems of green-cropping, mulching and the use of composts have been carried out within the demonstration area. This will continue, but in all sections compost will continue to be the basic manure. Part of the original area has now been reserved purely for demonstration and will be managed and cropped in strict accordance with the rotational and manuring scheme laid down by the late Dr. Rayner.

The long term trial laid down in 1950 on Bagshot Sand at Bramshill heathland nursery, Berkshire, was continued in 1952. The trial was established with large plots to run over a long period for comparison of the cumulative effects of regular manuring with inorganic fertilizers, composts or both, when the land is cropped annually with Sitka spruce seedlings. In 1952, the third year of the trial, compost slightly reduced the total yield of one-year seedlings compared with plots receiving no manure or fertilizer treatment. Fertilizer and compost applied alone increased the seedling heights at one year to a similar extent. The height growth on plots receiving combined compost and fertilizer treatment showed no increase over that for plots receiving fertilizer alone or compost alone. Thus, after three year's treatment all methods of manuring increased seedling growth to about the same extent. This result contrasts with that obtained in 1951, in the same trial, when plots receiving balanced fertilizer each year showed considerably greater growth of one-year seedlings than any other treatment.

Seedbed Compaction

A recent survey of methods used in Conservancy nurseries for compacting seedbeds showed that there was no consistent method in use. Seedbed rolling is conducted in different nurseries either before sowing, after sowing, or after applying the seedcover, or using the roller at two different stages in the seed sowing routine. As a result an experiment was conducted at Wykeham to test the effect of compacting seedbeds with rollers weighing $1\frac{1}{4}$, $2\frac{1}{4}$ and $3\frac{1}{4}$ cwt., before sowing, and with a $1\frac{1}{4}$ cwt. roller after the application of the grit cover. A light tamping board, one foot square, was used for lightly pressing the seed into the bed surface as an additional treatment.

Germination figures showed that the greater the degree of consolidation *before* sowing the greater is the speed of germination. Similarly, assessments at the end of the season showed that the heaviest roller produced the tallest seedlings and the highest yield of seedlings. Firming the seed lightly into the bed before covering made no appreciable difference to heights or yields, and similarly rolling after applying the grit produced no significant effects. Further experiments to determine the desirable limits of compaction in different soils and in different seasons are now in progress, together with trials of ways of measuring the degree of compaction.

Seedbed Covering Media

At Newton, equal covering depths of Speymouth grit and ordinary soil covers were compared as media for covering lodgepole pine, Japanese larch, Norway spruce and Douglas fir seed. From Table 6 it will be seen that only lodgepole pine grew taller on the grit, but that grit cover increased the yield of seedlings for all species.

HEIGHT GROWTH AND YIELD OF VARIOUS ONE-YEAR CONIFER SEEDLINGS, SEEDS COVERED WITH SPEYMOUTH GRIT OR SOIL AT NEWTON NURSERY IN 1952

Table 6

Species	Mean Heights in ins.		Nos. per sq. ft.		Nos. per lb. of seed in thousands	
	Soil	Grit	Soil	Grit	Soil	Grit
Lodgepole pine	1.09	1.16	69.7	75.8	47.4	51.6
Norway spruce	1.28	1.06	231.7	248.5	93.6	100.4
Japanese larch	1.53	1.43	97.7	110.3	50.7	65.9
Douglas fir	2.28	2.11	94.3	122.7	39.5	44.6

Soil Conditioners

A trial was carried out at Ddwylig nursery, St. Asaph, North Wales, to test 'Krilium' as a soil conditioner for improving the mechanical structure of a high clay content soil, and to discern its effects on subsequent production of tree seedlings. 'Krilium' was applied to prepared seedbeds in April, 1952, and one week later Scots pine, Japanese larch, Douglas fir, Norway spruce and Sitka spruce were sown as test species.

Examination of seedling development over the first season showed that the treatment had no measurable effect on germination, survival or height growth with any of the test species. There was no obvious change in the physical nature of the soil after treatment, but analysis showed a slight increase in the formation of stable soil aggregates. These plots will be retreated and re-sown in 1953 to provide a further test.

A similar experiment in Scotland was laid out on a clay soil at Tulliallan nursery. Four concentrations of 'Krilium' were tried, and the ground was sown with Scots pine and Sitka spruce. Sowing took place approximately three weeks after applying the 'Krilium'. Germination assessments showed that 'Krilium' had a very marked depressing effect upon the speed of germination of both species. Final height growth, and numbers of seedlings, were not affected by any treatment. In spring 1953 a frost lift assessment was conducted to determine whether improved soil drainage on 'Krilium' treated plots has helped to minimise frost lift. There were slight indications that it had assisted in this respect, but the benefit was not of practical importance.

Seedbed Watering and Irrigation

The trials of an overhead sprayline sprinkler system for seedbed irrigation were continued into their third year at Kennington nursery, Oxford. The object of the trials has been to assess the response of seedling conifer crops to water applications regulated according to soil moisture requirements. Two watering regimes were tested; in the first, water was applied whenever the soil moisture deficit attained 0.5 inches and the second when the deficit attained 1.5 inches, and results are shown in Table 7.

The rainfall during the period May to September was well below the average for the nursery, and was considerably lower than the rainfall during the period in 1950 and 1951 when similar trials were conducted.

RAINFALL AND WATER APPLICATION MAY—SEPTEMBER, 1952

Table 7

Month	Average Rainfall for Nursery (inches)	1952 Rainfall (inches)	Irrigation Water Applied (inches)	
			Treatment 1	Treatment 2
May	1.8	2.07	2.30	2.06
June	1.8	1.02	3.29	1.99
July	2.6	0.32	4.28	3.33
August	2.0	3.75	1.41	—
September	2.2	1.10	—	—
Total	10.40	8.26	11.28	7.38

The heaviest watering treatments were applied during the driest months, June and July. The monthly rainfall for May, 1952 is slightly misleading, as although the total is above the monthly average, precipitation was unevenly distributed. In the second half of May there was a period of 17 days without rain except for two falls of 0.27 inches and 0.01 inches. During this period, the screen maximum temperature exceeded 70°F. on 8 occasions.

The dry period in May came at a critical stage in the development of seeds sown in late April, and for some species, watering during this period increased germination and the number of seedlings surviving. All species sown showed increased growth on irrigated plots, but seedbeds of Sitka spruce showed the most marked response (vide table 8).

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

Table 8

Treatment	Total Seedling Production per lb. of Seed sown	Seedling Mean Height at end of Season (inches)
No Irrigation	5,000	0.83
1	48,000	2.10
2	52,000	2.03

Comparison of compost and fertilizer and compost manurial treatments within each irrigation plot showed that both compost and fertilizer greatly increased growth on watered plots, while the manurial effects on unwatered plots were slight. Watering greatly increased the production and growth of one year seedling Douglas fir, Japanese larch and *Thuja plicata*, and there was an appreciable growth improvement in Corsican pine. This result is a marked contrast to those obtained in 1950 and 1951 when seedlings of Douglas fir, Corsican pine and Japanese larch were unaffected by watering.

The results for Sitka spruce have been consistently good over the three years of the trial, even in 1950 and 1951 when rainfall for the May-September period was above average. One of the greatest effects of irrigation is to increase germination and survival during a period of dry weather after sowing.

A large scale seedbed trial was carried out for a second time at Widehaugh nursery, Northumberland. The 1951 results for Sitka spruce, Norway spruce, Scots pine, and Japanese larch, were almost completely negative in spite of low rainfall in the early part of the season. The growth of all species was poor on all treatments and it seemed likely that factors other than soil moisture were limiting. Accordingly, in 1952, formalin was applied for partial sterilzation of the soil as a possible remedy for the overall low productivity encountered in 1951.

The 1952 rainfall for the period from May to September was below that for the same period in 1951, and well below the average for the locality except for the month of June in which 3.19 inches of rain fell. The effects of irrigation treatments were small. The growth of Scots pine, Norway spruce and Sitka spruce was increased slightly, but there was no corresponding increase in total seedling production. The only pronounced response was that of Japanese larch which showed increased production and growth on watered plots. Formalin had no effect except for a slight increase in the growth of Japanese larch, and the treatment had no influence on the response to watering.

Intensive Raising of Sitka spruce in Heated Frames

At Tulliallan Nursery a successful attempt was made to obtain three sucessive crops of Sitka spruce seedlings in one season in an electrically heated frame. Boxes fitted with sliding bottoms were used for the purpose, so that the plants and soil could be removed *en bloc* into prepared shallow trenches in the nursery and the boxes refilled with soil and re-sown. The first sowing took place in December 1951, and the first crop of seedlings was removed in early February; after renewing the soil and re-sowing in mid-February a second crop was removed in mid-March and a third crop was grown and removed from the frame by mid-May. The two early sowings were given outside overhead frost protection after removal from the heating frame. The third sowing required no overhead protection after removal in May.

Plants in adjacent boxes, which were sown in early December, and removed from the heat in mid-May, did not produce taller seedlings at the end of the year than seedlings sown in February and removed in March and covered with branches. This result is believed to be due to the fact that either daylight length or intensity of illumination from January to April is limiting to plant growth. It was noted during the course of the experiment that early sown treatments germinated two to three weeks after sowing but did not grow beyond the cotyledon stage until May in spite of a soil temperature of approximately 60°F.

Of the different methods employed to "harden off" the seedlings, lath covers were the most successful. Spruce branches were second best, and cloches proved to be the worst of the three. Seedlings "hardened off" under branches produced the tallest plants at the end of the season, a fact which in all probability is due to the slight mulching effect of the spruce needles left on the ground after removing the branches.

Soil Heating and Night Illumination

In late December 1951 and early January 1952 unreplicated areas in an electrically heated frame were sown with Scots pine, Norway spruce and Sitka spruce. Overhead illumination producing average intensities of approximately 4 and 15 foot candles on the seedbed surface was given for periods extending from one hour before sunset to two hours before dawn each day, and from three weeks after sowing until late July, in order to test the response of

the seedlings to extended periods of illumination. 100 watt and 40 watt gas-filled electric light bulbs were used for illumination purposes.

End of season results (see Table 9 below) indicate that Scots pine responds slightly to extended illumination at night at the intensities used, and that Norway spruce and particularly Sitka spruce are very responsive.

MEAN HEIGHTS OF SEEDLINGS RAISED ON SOILS MAINTAINED AT 60°F. AND WITH A NIGHT ILLUMINATION OF 4 OR 15 FOOT CANDLES

Table 9

	Scots pine			Norway spruce			Sitka spruce		
	Night Illumination in Foot Candles								
	0	4	15	0	4	15	0	4	15
Mean Heights in inches	4.0	4.2	4.8	2.9	3.9	5.3	3.9	4.6	6.0

Root Pruning of Seedlings

Experiments were started at Bramshill nursery, Berkshire, in 1951 to examine mechanical undercutting of seedlings as a possible cheaper alternative to the normal transplanting techniques. Test beds of Corsican pine were sown at several densities in 1951. In February 1952 the seedlings were undercut in situ at three to four inches below soil, using a tractor-mounted root pruner. Other seedlings were transplanted in the normal way for comparison. The results of an examination of the plants at the end of 1952 are summarised in Table 10.

COMPARISON OF GROWTH RATES OF SEEDLINGS, ROOT PRUNED PLANTS AND NORMAL TRANSPLANTS OF CORSICAN PINE, ALL TWO YEARS OLD

Table 10

Treatment (1)	Mean Height (Inches) (2)	Mean Dry Wt. (Grm.)		Root/Shoot Ratio (By Weight) (5)
		Shoot (3)	Root (4)	
Untreated (2+0 seedlings)	4.46	2.74	0.59	0.21
Root pruned at 1+0—(1 u 1 plants)	3.19	2.13	0.72	0.34
Transplanted at 1+0 (1+1 plants)	2.81	4.35	1.77	0.40
Sig. Diff. (P=0.05)	1.70	1.18	0.23	—

Note.—Figures in Columns 3, 4, and 5 are based on measurements on 80 plants selected at random from each treatment.

Root pruning tended to reduce the height growth in the year of treatment, and transplanting resulted in a significant growth check. Transplanting increased the dry weight of shoot and root, and also increased the ratio of root weight to shoot weight compared with untreated or root-pruned plants. Root pruning also increased the root-shoot ratio compared with untreated plants.

The character of the root systems differed from one treatment to another. Transplants had the greatest proportion of fine or "fibrous" roots and root-prunted plants had a slightly greater proportion than untreated seedlings.

Transplanting has resulted in the production of shorter, heavier and bulkier plants, with a greater root mass and proportion of fibrous roots than other treatments. However root pruning appreciably increased the root mass and root/shoot ratio. The practical significance of these differences is now under test in forest planting trials.

In Scotland, a root pruning experiment was carried out at Newton nursery (Moray) in 1951 in which Scots pine and Japanese larch grown at normal, half normal and quarter normal densities, were undercut at a three inch depth in February 1952 with a sledge type of root pruner. Plants from each of the densities were lined-out to produce one-plus-one transplants, and other plants were left to produce second year seedlings. Assessments based on a twelve-plant sample of each type of material are reproduced in Table 11.

SUMMARY OF ASSESSMENTS MADE ON SEEDLINGS, ROOT-PRUNED PLANTS, AND NORMAL TRANSPLANTS FROM THE 1951 UNDERCUTTING EXPERIMENT AT NEWTON NURSERY

Table 11 — All plants aged two years when assessed

Factor	Type of Plant	Scots pine on formalin sterilized soil	Scots pine on unsterilized soil	Japanese larch on unsterilized soil
Mean Heights of seedlings or transplants, in inches	2+0	6.4	5.8	12.9
	1 u 1	5.3	4.7	12.3
	1+1	3.9	3.6	12.4
Root/Shoot ratio by weight	2+0	0.34	0.37	0.59
	1 u 1	0.32	0.50	0.65
	1+1	0.52	0.59	0.85
Total number of Secondary and Tertiary roots over 1 inch in length	2+0	13.3	11.2	16.8
	1 u 1	19.2	17.9	18.3
	1+1	28.9	18.4	17.8

Note.—1 u 1 = Plants root pruned *in situ* in seedbeds after one year's growth in the seedbeds.

The table indicates that undercutting in February checked the height growth of plants, but not as severely as transplanting. The root-shoot ratio by weight was generally increased by undercutting, but not so markedly as by transplanting. Undercutting promoted the growth of root fibre but again not so markedly as transplanting.

Plants from this experiment have been planted in the forest at three centres to compare growth and survival.

Chemical Control of Weeds in Forest Nurseries

Weed Control in Seedbeds

A series of large scale trials was carried out in ten nurseries throughout Britain with the object of testing pre-emergence and post-emergence applications of mineral oils for weed-control in seedbeds under a variety of conditions. Previous trials in 1950-51 indicated that pre-emergence treatment of seedbeds with vaporising oil was highly successful for all the species and conditions

tested, and in early 1952 the technique was recommended for practical use. The treatment now recommended involves application of vaporising oil at 60 gallons per acre four or five days before commencement of tree emergence, by means of an air pressure spray.

However it is important that the above dosage is not exceeded, or crop germination may be retarded. Slow germinating species such as Sitka spruce and Douglas fir are particularly sensitive and may be seriously damaged if the recommended rate is exceeded.

Allyl alcohol and sodium 2,4-dichlorophenoxyethyl sulphate, (SES), applied to newly sown beds of Scots pine and Sitka spruce gave promising results. Allyl alcohol in 0.2-0.4% solution at 1 gallon per square yard before sowing, greatly reduced weedgrowth throughout the season without damage to the tree crop. This chemical is dangerous and offensive to handle, and suitable methods of application will present practical difficulties.

SES, a 2,4-D formulation which becomes actively phytotoxic only after contact with soil for several days, was tested both as a pre-emergence and post-emergence treatment to seedbeds. The compound reduced the numbers of annual weeds but it was impossible to make precise conclusions on its properties as a weedkiller, owing to the small numbers of weeds occurring over the whole experiment.

Application of SES at 1 to 3 lb. per acre shortly before or after seed sowing was injurious to pine and spruce, the seedlings of which became discoloured and showed pronounced malformation of the stem and needles. The same treatments applied a few days before tree emergence caused negligible damage to the tree crop. Trials of the chemical as a post-emergence treatment showed that first-year seedlings of pine and spruce were uninjured by repeated application at rates up to 2 lbs. SES per acre. Increasing the application rate to 4 lbs. per acre caused serious malformation of Scots pine seedlings, but seedlings of Sitka spruce appeared to be unaffected.

Undecylenic acid has shown some promise for selective weed control in spruce. Application to one-year seedlings at 0.25-0.50% in emulsion at 100 mls. per square yard on four occasions between June and October caused no crop damage and led to an appreciable reduction in weed growth. As in the trials on SES, weedgrowth was insufficient to permit reliable conclusions on its herbicidal properties, and the trials are to be continued in 1953. In the same way trials of ferrous sulphate and zinc sulphate as selective weedkillers gave inadequate results and must be continued.

At Kennington nursery, Oxford, and at Wykeham and Mabie nurseries, an investigation was made of sensitivity of Scots pine and Sitka spruce seedlings to post-emergence sprays of white spirit applied at different stages of growth. At no stage were seedlings killed by application at rates up to 60 gallons per acre. In some cases seedling crops were damaged, and this normally occurred as a growth check which did not always become apparent until some time after treatment; the effect may not be accompanied by obvious symptoms such as a scorch of foliage. The results of this investigation and additional trials on Douglas fir, Lawson cypress and *Thuja plicata* confirmed the conclusion from previous experiments that white spirit is an effective selective weedkiller for conifers but serious damage can be done to the tree crop if the sprays are applied immediately after seedling emergence, or within a period of one month of the shedding of the testa or seed coat.

During the year a series of experiments was started at Bramshill nursery, to examine the use of complete weedkillers such as sodium chlorate, sodium arsenite and sodium trichloracetate for application to weedy growth some months before cropping with forest trees, with the object of reducing the weed population prior to sowing or planting. First results are promising but it is too early to draw firm conclusions.

In Scotland, a large scale demonstration of vaporising oils and white spirit as weedkillers on seedbeds was conducted in liaison with Conservancy staffs at the following nurseries: Millbuie (Ross-shire), Glenfinart (Argyll), Wauchope (Roxburghshire), Inchnacardoch and Fleet. The treatments compared pre-emergent sprays of vaporising oils and white spirits at rates of 100 gallons per net acre of seedbeds, either singly, or in combination with post-emergent sprays of vaporising oils at 30 gallons, or white spirits at 50 gallons per net acre. Included in the treatments were pre-emergent burning with the Hauck torch. Results showed that pre-emergence sprays alone were safe for all the species under test (viz.: Scots pine, lodgepole pine, Norway spruce, Sitka spruce and Douglas fir) and that they produced a more efficient weedkill than burning with the Hauck torch. Post-emergent sprays were not damaging to Scots pine, but other species proved to be increasingly susceptible to damage in the order: Norway spruce, Sitka spruce, lodgepole pine and Douglas fir—the last two species being very susceptible.

Weed Control in Transplant Lines

The use of mineral oil weedkillers in transplant lines appears to be a practical proposition, but the results have been found to vary considerably according to the species and the stage of growth at which they are sprayed. In 1952, trial applications were made to rising one-plus-one transplants of a range of species to gain information on the oil, dosage and dates of application and their effect on transplant development. Oils were tested as single and repeated applications at dosages ranging from 60—150 gallons per acre from May to October.

Trials on Corsican pine, Norway spruce and Sitka spruce showed that vaporising oil was damaging to the trees particularly when applied in mid-summer. White spirit applied as an overall spray caused negligible damage to the crop providing the number of applications did not exceed five over the season. Douglas fir was slightly more sensitive and more than four applications caused foliage scorch and growth retardation.

All species were most liable to injury from sprays applied in July and August, and application of vaporising oil during this period had disastrous results in the case of Douglas fir.

Tests on transplants of oak and beech showed these species to be highly sensitive to repeated treatments when they are actively growing. Applications in September and October caused no damage, and sprays can be applied and repeated safely when the plants are inactive in autumn, winter, and early spring. This is also true for Corsican pine, Norway spruce and Sitka spruce. It now seems clear that all species are most liable to damage when oils are applied during hot, dry weather, particularly if the soil is excessively dry.

All the foregoing conclusions are based on trials involving overall spraying of transplant lines. Work is now proceeding on development of a technique for accurate inter-row spraying.

Season and Date of Lining-out

The 1950 lining-out experiment was repeated at Inchnacardoch, Tulliallan, Benmore, Wykeham and Mabie, Dumfries-shire; using rising one-year and rising two-year Scots pine and Sitka spruce seedlings. Lining-out took place at intervals from late May 1951 at Inchnacardoch and Benmore and early July at the remaining nurseries, to early April 1952. As in previous years, the seedlings were separated into one inch height classes at the time of lining-out in order to determine the relationship between initial size and subsequent survival and growth.

Rising one-year Scots pine. Results confirmed the 1950 work which showed that plants less than two inches tall lined-out in late autumn or early winter are very susceptible to frost lift. Plants over two inches tall produced satisfactory results at most nurseries when lined-out from September to October, or in early spring.

Rising two-year Scots pine. Plants three inches and over in height, lined-out in early July, produced highly satisfactory results at all nurseries except Tulliallan. Between August and spring, results were not as successful. At Benmore, Inchnacardoch and Mabie the lining-out of plants over four inches tall gave satisfactory results at all periods, with the possible exception of mid-November. Early spring lining-out was very satisfactory at all centres and for all height classes.

Rising one-year Sitka spruce. Because of the slow rate of growth of this species, early spring is the only practical lining-out period for this class of plants.

Rising two-year Sitka spruce. All plants over three inches tall were successful when lined-out in July at all centres, and in August at four of the nurseries. Plants over four inches tall can be lined-out successfully in September in the majority of nurseries. Early spring treatments also gave satisfactory survival and usable yields. Generally it appears that the taller the plant the more successful are the autumn and early winter periods for lining-out. But equally good results were obtained with smaller plants lined-out during July.

This experiment is being continued to obtain average results over a number of years.

Maleic Hydrazide as a Growth Inhibitor

At Tulliallan and Mabie one-year seedlings of Scots pine, Japanese larch, Douglas fir and Sitka spruce were sprayed with maleic hydrazide, diluted in water to concentrations of 0.05, 0.1 and 0.2 per cent. The object of the treatments was to determine whether the chemical would retard the date of flushing and so reduce the amount of growth in seedbeds which are required to remain for a second year. Applications were made in spring when the buds of plants under test began to swell.

Maleic hydrazide at any of the concentrations under test did not affect the date of flushing. At Tulliallan, growth of all species was reduced in proportion to the concentration of the chemical, but at Mabie it produced no effect at all on height growth. Resulting seedlings at Tulliallan appeared slightly contorted and stunted and they are to be lined-out in 1953 to determine whether the material has any residual effects on growth in the second year.

SILVICULTURAL INVESTIGATIONS IN THE FOREST

By R. F. WOOD and M. V. EDWARDS
Silviculturists

Derelict Woodlands

In this project the principal experimental aim at this stage is to lay down a series of experiments, covering the main soil and cover types, comparing the crops and costs resulting from a selection of treatments graded on intensity of effort.

Work in the year under review has included tending operations on experiments laid down previously and the establishment of new experiments in the series. The experiment at Gardiner, Wilts., on the conversion of hazel coppice to beech high forest, has only required one weeding during the season; costs ranged from the low figure of 3s. 9d. per acre in the "Small Groups" to £3 15s. 0d. per acre in the "Clear Cut" treatment. In the experiment dealing with the rehabilitation of a war-felled broadleaved wood at Haldon, Devon, weeding was necessary only in the plots fully replanted with one-plus-one beech stocks; the cost being £4 5s. 0d. per acre. Tending was not required in treatments involving acceptance of natural regrowth or 'enrichment' with large beech transplants.

In the rehabilitation demonstration at Weston Common, Alton, Hants., the initial treatments of the squirrel-damaged ash and sycamore advance growth has been completed; and in some of the gaps left by the removal of the poor overwood trees a useful number of natural beech seedlings have appeared.

Two further experiments in the general series have been laid down this year, the first in a low cover type on clay loam at Halton Wood, Coed y Goror Forest, Denbigh; and the second in high cover on heavy clay at College Wood, Bardney Forest, Lincs.

The Coed y Goror experiment follows essentially the same lines as that laid down at Haldon the previous year, as described in the Report on Forest Research for the year ending 31st March 1952. Treatments included:

1. Clearance of regrowth and full replanting with broadleaved and conifer mixtures.

2. Clearance and full replanting with pure conifers.

3. Acceptance and tending of best elements in natural regrowth with enrichment using large beech transplants.

4. Leaving the existing regrowth for ten years or so in the hope that treatment will become easier and will yield saleable produce.

5. Untouched control plots.

Treatment 3 was split, as at Haldon, for different methods of protection from rabbits, (*a*) full rabbit fence, (*b*) no rabbit fence, but individual large transplants sleeve netted, (*c*) no special protection. The two latter treatments are being carried out with rabbit population controlled to a low level, as it is felt that large transplants and selected natural stems may stand a reasonable chance where rabbit pressure is light.

The experiment covers a total of about 27 acres and is divided into 3 blocks; all work has been carefully timed and mean figures for man/hours per acre for each treatment obtained; when converted into cash at the rate of 2s. 6d. per hour they give the mean costs shown in Table 12 below.

COSTS OF DIFFERENT METHODS OF REHABILITATING A FELLED HARDWOOD SITE AT COED Y GOROR FOREST, DENBIGHSHIRE

Table 12

Treatment	Cutting Inspection Racks	Prep. Ground	Plants and Planting	Protection	Pruning	Total
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1.	1 18 8	26 7 6	19 1 7	7 10 1	—	54 17 10
2.	1 18 8	26 7 6	15 18 0	7 10 1	—	51 4 3
3.(a)	1 18 8	1 6 6	2 1 10	7 10 1	16 0	13 13 1
3.(b)	1 18 8	1 6 6	2 1 10	2 15 9	16 0	8 17 9
3.(c)	1 18 8	1 6 6	2 1 10	17 3	16 0	7 0 3
4.	1 18 8	—	—	7 10 1	—	9 8 9
5.	1 18 8	—	—	7 10 1	—	9 8 9

At College Wood, Bardney, the subject of experiment is a poor but fully stocked stand of natural origin on a heavy clay soil. It is about 35 feet tall and carries over 600 stems to the acre, the principal species being ash and birch of coppice origin each contributing about 40 per cent; oak coppice provides some 13 per cent and lime and aspen 1.5 per cent each. It was not considered that the stand had any prospects of producing a reasonable yield of saw timber. The choice of methods of conversion appeared to be between complete clearance with full replanting, and heavy thinning with retention of the best material coupled with underplanting. The former method is particularly applicable to replanting with oak and a Norway spruce nurse crop, it also provides a useful return to offset costs, but may involve a temporary site deterioration with invasion by moisture loving grasses and consequent prolongation of establishment. Underplanting restricts the choice of species to shade-tolerant trees and the remaining stems may be difficult to extract, but the microclimate and soil conditions may be more favourable, and the ground vegetation easier to control. It was felt also that it would be of interest to compare coniferous and broadleaved crops on this site. Hence the following treatments were adopted.

1. Clear cut the existing stand and replant; this method being split for choice of species.

(*a*) 3 row—3 row mixture of oak-Norway spruce, with the object of forming a full final crop of oak and using the spruce as a nurse and to provide early cash returns.

(*b*) Plant fully with Douglas fir which should grow fast and suppress the coppice and weed growth quickly.

2. Thin the existing stand uniformly and underplant with a shade-bearing species. This treatment was split for choice of species:—

(*a*) Beech

(*b*) *Thuja plicata*

The experiment covered just over twelve acres, including small 'no treatment' controls, and was divided into two blocks. The 'clear cut' treatments in each block totalled three acres, and it was thought that such areas were large enough to deny any advantages of shelter to the planted trees.

All the work done, and the produce prepared from each plot, was carefully recorded, but at the time of writing, records of the sales of produce are not quite complete. Nevertheless there will evidently be a marked difference in the initial nett costs of the various treatments and a reasonably accurate estimate shows that the nett costs, deducting the value of the produce from total cost of preparation of ground, preparation of produce, extraction, and planting, are approximately:—

Treatment 1. Clear cut and replant. £23 10s. 0d.

Treatment 2. Thin and underplant. £35 5s. 0d.

The difference is due, of course, to the larger quantities of produce prepared from the clear cut plots.

As in all costed forest experiments too much importance must not be attached to the first year's costs; it is the total cost of establishment which will be significant, and a number of factors may affect the present trend.

Trial Plantations on Difficult Sites

In Scotland and North England

For the fourth year in succession a large programme of experimental planting on difficult sites has been undertaken. Some twenty new experiments were started while some existing experiments were extended. Almost forty older experiments were concluded, the results written up, and their future use decided.

As an example of the use to which certain older experiments may be put, the treatment of Experiment 14 planted in 1930 at Kielder Forest, Northumberland, may be cited. Originally planted to test the need for phosphate for Norway and Sitka spruce on *Molinia* ground, the experiment has been ended at twenty years with the conclusion that phosphate is not essential. The layout of this experiment is such that it now provides four plots of each species, which are being used to give comparative growth data for the two species on the same relatively poor ground type. Such comparisons are surprisingly rarely found in the forests, because these species have generally been allocated to different ground types. The majority of the completed experiments however are not suitable for continuation, and no further records are maintained, thus freeing staff for new work.

Trial Plantations, Shelter Blocks and Shelter Belts

The majority of the plantations being formed on ground normally classed as unplantable fall in the above three classes. Though, in the long run, their form and use will be very different, at planting the technique used is almost identical; only the scale is varied. A shelter block may be usefully distinguished from a trial plantation in that timber growing is a secondary object and thus the plantation can be smaller. In contrast a shelter belt may be defined as being of the minimum width to obtain a useful height to give shelter. The first post-war experimental trial plantations planted in 1946-1949 on deep peat classified as unplantable at Inchnacardoch, Inverness-shire and Strathy, Sutherland, continue to make strikingly rapid growth, opening new horizons for the successful establishment of tree crops. These experiments are essentially long term. Pitwood undoubtedly can be produced on deep peat, but it remains to be seen whether timber production will be achieved. However,

in the meantime, there is every incentive to press on with the establishment of pilot plantations under a wide range of locality and site conditions.

Table 13 gives details of this year's work.

TRIAL PLANTATIONS, SHELTER BLOCKS AND BELTS PLANTED IN 1952-53
Table 13

Site	Approx. area acres	Main features of site	Main species
Watten, Caithness	30	Exposed deep poor peat	Shore pine
Skiall, Caithness	17	Good peat types and mineral soil, exposed	Scots pine Jap and hybrid larch Norway and Sitka spruce
Reay, Sutherland	5	Poor peat types	Shore pine
Fetteresso, Kincardineshire	5	Exposed high altitude heathland	Lodgepole pine
Halifax Corporation Water Catchment area, Yorks.	14	Smoke polluted and exposed, often poor soil in addition	Lodgepole pine Sitka spruce Japanese larch
Shetland Islands, shelter block	3	Exposed, moderate—poor soil	Shore pine with hybrid larch
Shetland Islands, shelter belt	2	Very exposed, poor soil	Shore pine and mountain pine

Shore pine=*P. contorta* (coastal form): Lodgepole pine=*P. contorta* var. *murrayana.*

The plantations at Watten and Skiall were continued on behalf of the Department of Agriculture for Scotland, and this year's work completes a set of three areas (Forss, Caithness, is the third) where blocks have been planted under severe conditions of exposure and often on poor soil and on peat. This work, started in 1949, has involved planting 150 acres; and the opportunity has been taken to include many experiments on points of technique within the main blocks. This year's plantation at Skiall was on the best land within the three blocks, and should provide at least useful estate timber. Watten plantation has been described by Bartlett (1953).

The work at Reay was undertaken by Pulford Estates Ltd. to the prescription of the Research Branch, and will serve as a valuable link between existing experimental areas in northern Sutherland and Wester Ross. The plantation at Fetteresso is on land classified as unplantable in a Commission forest.

This year's planting on smoke polluted sites near Halifax in co-operation with Halifax Corporation, completes the initial phase of the work. Some forty acres have been planted over a range of seven combinations of ground type and exposure, all subjected to industrial fumes from the encircling chimneys of West Riding and Lancashire.

Following last year's exploratory visit, two experimental plantings have been made on the Mainland of Shetland. A shelter block of three acres (9 x 3½ chains) has been planted under a hill-farming scheme at Kergord, with Research Branch supervision. The owner was encouraged to undertake this by the success of seven acres of plantations and belts planted in 1909-1923. These plantations have been briefly described by Venables (1948).

A shelter belt (15 x 1½ chains) was planted by the North of Scotland College of Agriculture on a reclamation scheme at Sullom, once again to Research Branch specification.

In Shetland also three small species trials were planted in varying site conditions to give information on early growth, in preparation for any further shelter belt schemes. *Pinus contorta* is a new species in these islands, and reports of its success in the Faroe Islands lead to hopes that it may prove useful.

Another aspect of the shelter belt work is the extension round the edge of the 80 acre Watten block of the series of shelter edges started in 1951. As in the shelter belts the basic species are prostrate and upright mountain pine, and coastal *Pinus contorta.*

During the year exploratory work in connection with pilot planting schemes has continued in Hoy, Orkney; in Sutherland and in the Glen Trool National Forest Park (Kirkcudbrightshire).

A large scale trial of different species for use in mixture with *Pinus contorta* on deep peat has been planted at Wauchope forest, Roxburgh, to the same prescription as was used last year at Watten, Caithness.

The selection of volume plots in experimental areas to give details of production on poor land continues. Most interesting are the first volume figures for the Lon Mor, Inchnacardoch, Inverness-shire, the oldest experimental area on poor deep peat. First results are shown in Table 14.

STOCKING AND VOLUME OF PLOTS ON THE LON MOR, INCHNACARDOCH FOREST.
Table 14

Species	Expt.	Age	Top Ht.	Stems per acre	Standing Volume	Quality Class
			feet			
Scots pine	19.P.26	28	28	650	580 H ft.	III
Pinus contorta	47.P.28	26	31	890	1030 H ft.	Equivalent to II SP
Pinus contorta	52.P.28	25	31	980	1030 H ft.	Equivalent to II SP
+QC II SP for comparison		25	32	1030	980 H ft.	—

H ft.=Hoppus feet over bark.

It must be regarded as most satisfactory that the production of *Pinus contorta* on poor deep basin peat is found to be equivalent to Quality Class II Scots pine, at any rate in its earlier years.

In Southern England and in Wales

Sand dunes. A small trial of direct sowings of Corsican pine, *P. radiata* and *Pinus pinaster* was carried out on a fixed dune at Newborough Warren, Anglesey where difficulties in establishment of transplants have been experienced. The experiment includes certain fertiliser comparisons. On an unfixed dune in the same area a type of temporary fibre pot was used to give local stability for both transplants and sowings of Corsican pine, with and without thatching of the sand surface.

Western heaths. At Wilsey Down, Cornwall, a start was made on a small scale with experimental treatments aimed at bringing Sitka spruce out of check; namely interplantings with *Pinus contorta* and Lawson cypress (a curiously successful species on this heath) coupled with direct sowings of broom and manurial treatments.

Opencast Ironstone Workings. Some further study of the older plantations on worked over land was made during the year to complete the investigation.

Colliery Waste Tips. A survey of plantations on waste heaps throughout the main colliery districts was completed during the year, and a summary of the findings is printed elsewhere in this Report. (*See* page 43.)

Ploughing

During the year Mr. C. W. Yeatman, an Australian working on root development on the heathlands, produced evidence on the value of complete ploughing as an aid to the development of a balanced and efficient root system.

Complete ploughing has been repeatedly carried out in experiments for twenty-five years but the extra growth has to date never compensated for the considerable additional cost over the current method of ploughing a single furrow for each line of trees. At Mr. Yeatman's suggestion trials were commenced on disc type ploughs of the stump-jump pattern widely used in Australia.

Relief of Checked Sitka Spruce

The experiments initiated in recent years are now starting to give useful information. The striking response to nitrogenous manuring of checked Sitka spruce at Broxa, Langdale Forest, Yorkshire, has proved to be shortlived. In general only the methods involving complete suppression of the ground vegetation by screefing or mulching give an effective stimulus which is likely to lead to canopy formation. (Weatherell, 1953). Such treatment on any scale would be very expensive and in some cases replanting with a new species might be cheaper.

Draining

Three trials on the use of explosives for draining have been carried out. This system has made great strides in Norway since the war.

The trials at Newcastleton and Kielder forests have been successful in producing a deep drain of a type which might prove useful though it is not one to which we are at present accustomed, being three to four feet deep and about six feet wide. The Norwegians use such drains at two to five chains per acre.

The trials failed in so far as economics were concerned. The Norwegians use sympathetic detonation, but the only trial of this method undertaken in Great Britain by Mr. Thurman Moe, Director of Drainage Operations in Norway, was unsuccessful, apparently due to the dryness of the soil. Two trials, using fused charges, were successful technically, lengths of drains up to four chains being produced in a very short time, but the costs were heavier than those of digging. Four acres of 70-year-old blown plantation at Kielder were successfully drained by contour ditches at two to three chains apart. Previously the majority of the drains had followed the direction of steepest slope. The main problem is that the use of explosives would be most valuable in blown or felled woodland, where ploughs cannot operate and hand work is expensive, but it is here that the complete waterlogging required for sympathetic detonation will not be found. It remains to be seen whether this difficulty can be overcome.

Species and Mixture Trials

The species collection at Kielder Forest, Northumberland, has been completed this year by the addition of a number of plots of simple but relatively untried mixtures such as Sitka spruce/Douglas fir or Norway spruce/western hemlock. The aim is to extend the range of species in use in the predominantly

spruce forests of the Borders. A similar set of plots has been commenced at Glen Trool Forest, (Kirkcudbrightshire).

A small trial of six species of Eucalyptus was established at St. Clements Forest, near Truro, Cornwall, the species and their seed origin having been selected by an Australian expert especially for British conditions.

At Speech House Arboretum, Forest of Dean, the following twenty-one new species were added to the collection:

Abies veitchii, *Betula lenta*, *Carya* spp., *Cedrus deodara*, *Cupressus nootkatensis*, *Ginkgo biloba*, *Gleditschia triacanthos*, *Larix occidentalis*, *Liriodendron tulipifera*, *Metasequoia*, *Nothofagus procera*, *Phellodendron* spp., *Pinus armandii*, *Pinus greggii*, *Pinus monticola*, *Platanus acerifolia*, *Pyrus torminalis*, *Quercus pyrenaica*, *Sophora japonica* and *Tilia cordata*.

New plots of the following species were planted at Wareham Forest, Dorset:

Abies alba, *Abies concolor*, *Abies firma*, *Abies veitchii*, *Abies lasiocarpa*, *Pinus nigra*, *Pinus excelsa*, *Pinus montana*, *Pinus monticola*, *Pinus taeda*, *Pseudotsuga taxifolia*, *Chamaecyparis pisifera*, *Libocedrus decurrens*, *Sequoia gigantea*, *Quercus borealis* and the hybrid *Pinus attenuata* x *P. radiata*.

At Thetford (Olleys and Lynford species trials) in Norfolk, plots of *Betula lenta* and *Nothofagus procera* were added.

In Benmore Forest Garden, near Dunoon in Argyll, a new working plan has now been in operation for three years, and the future form of the Garden is starting to take shape. Since 1950, the Garden has been divided into a number of genus blocks within which all plantings have been located. Many of the older plots, which are unlikely on account of their small size to give a true picture of the species under forest conditions, have been classified as temporary plots, and their replacement by plots of at least quarter of an acre is planned for the future.

At the end of 1952 the position in the Garden was:—

Pre war (1939) plots—	
Permanent plots in correct genus block	48
Permanent plots not in correct genus block	31
Temporary plots to be removed gradually as replaced	35
Post War plots 1949-51	31
Total	145

In addition a further sixteen plots were planted in the current year, and in almost all cases each plot exceeded a quarter of an acre.

A number of specimen trees or small groups are also being preserved. These are either of rare species, of which it has not been found possible to obtain sufficient plants for a plot, or they are the survivors of plots which have for the most part failed. They thus provide material of general interest and possibly of genetical value.

A start has also been made to determine the standing volume of those species which have reached the thinning stage.

Establishment of Hardwoods in Scotland

At Brownmoor Forest, Dumfries-shire, an experiment was laid down to compare the initial growth rate and survival of one-year-old wych elm seedlings (not root-pruned), and seedlings root-pruned in August of the year of sowing. In addition an experiment was started in which gean, wych elm, Norway

spruce and European larch are used as matrix species for pedunculate oak. This experiment was laid down on two sites, namely, a good site previously covered by hardwood scrub growing on old pasture land, and a marginal site of bracken vegetation growing on slightly podzolised soil.

Small pure blocks of red oak, beech, gean, wych elm, lime, sycamore, ash and Japanese chestnut were planted on the above two sites.

Ecological Studies

Ecological work in derelict woodland has been restricted to Marelands near Alice Holt in Hampshire, and to an extensive group of woods on Jurassic rocks lying seven miles north-east of Oxford and now administered under the ancient name of Bernwood Forest. A soil and vegetation survey was made of the Marelands Woods, which are of varied topography and comprise soils ranging from well drained fertile loams of the Malmstone to stiff glazed clays of the Gault. The much larger Bernwood group of woods is practically all on the Oxford Clay, but there are a few small exposures of Arngrove Stone, a local facies of the Corallian. Examples of the derived soils were examined in detail and the distribution of the main vegetation types noted.

Detailed records have been made in two quadrats in Oakley Wood and along two transects in Yorks Wood and Waterperry Wood respectively. It is expected that these records will make it possible to study the natural changes in the woody vegetation in certain types of derelict broadleaved woodland.

Ecological studies have been continued on three southern heaths in Dorset and Cornwall. In Wareham Forest, Dorset, the sites where afforestation has proved particularly difficult have all been examined and a report prepared on the special characters of the soil and natural vegetation of the types recognised. Several serpentine soil profiles were examined on Goonhilly Down, on the Lizard peninsula in Cornwall, where a new forest called Croft Pascoe is to to be started. The characters of the natural heath vegetation have been described and the main factors likely to influence tree growth have been critically appraised. Little experimental work has yet been possible on Wilsey Down in North Cornwall, where spruces planted 20 to 25 years ago are still in check over large areas, but a good deal of observational work has been done, and four small permanent quadrats have been recorded in detail in the affected plantations. Through the kindness of Dr. L. Leyton of the Imperial Forestry Institute, Oxford, representative samples of Sitka spruce needles and of heather foliage were analysed for nitrogen and phosphorus.

Provenance Studies

Japanese Larch

Japanese larch seed is normally obtained from Honshu Island in Japan in the mountains of Nagano (or Shinano) province to the north-west of Tokio. The natural distribution of the larch is comparatively restricted, not extending for more than 200 miles in any direction. Robak (1951: p. 41) stated that all the seed imported by Messrs. Rafn of Copenhagen before the last war came from the area around Mt. Yatsugatake. He has also stated (private communication) that his enquries indicated that the best seed collecting area was on the slopes of Mt. Fujiyama itself, but that it was not easy to obtain seed from this holy mountain for religious reasons.

In 1950 by special arrangement with the Sanwa Trading Company, some seed was obtained from trees about fifty years old at an elevation of about 1,500 metres (5,500 ft.) on Fujiyama Matu, the mountain itself. The seed was sown on May 8th, 1951 in Devilla woodland nursery, Fife, on well prepared

soil, side by side with seed from the usual general Japanese trade collection from Nagano province. The sowings were replicated seven times.

The Fujiyama seed was slightly larger and, by the tetrazolium test, showed a better capacity for germination. Based on this test the sowing densities for the two provenances were fixed at 740 and 450 square feet respectively per pound of seed, estimated to produce about 85 plants per square yard. When the result of the ordinary Copenhagen tank germination tests were received, they showed less difference between the two provenances, and indicated that the sowing rates adopted for the two lots might be expected to give 76 and 87 plants per square foot respectively. At the end of the season the actual results were 65 and 81 plants per square foot, confirming that the differences in germination were smaller than the tetrazolium test indicated, and as a result the Fujiyama plants had rather more room in the beds than the other provenance. In spite of this, they did not grow to such a large size (see Table 15). In general the seedbeds were patchy, as happened with many sowings in the rather poor weather of that summer.

At the end of the first year, therefore, it appeared that in spite of rather larger seed and better germinating capacity, the growth of the Fujiyama seed was inferior, rather than superior, to that of the general trade supplies.

The plants were then lined-out, all those over 1½ inches in height being included, and at the end of the season the one-plus-one transplants of the Fujiyama seed were still slightly inferior in size, but the difference was not significant. Both suffered slightly, but equally, from frost. In all other respects however, there were no differences between the two provenances.

The two lots of plants will be planted in Glen Isla forest in Angus and their subsequent growth studied in the future.

The data confirm those published in last year's annual report by showing that differences between the various consignments of seed usually received from Japan are small; although, as shown in the *Research Report* for 1949 (p. 51-52), there may be important differences between the progenies of individual trees.

SEED SIZE AND GROWTH OF JAPANESE LARCH PROVENANCES

Table 15

Provenance	Weight of 1000 seeds, gms.	Mean Height of all 1 year seedlings, ins.	Seedlings over 1½" tall %	Mean Height of 1+1 transplants, ins.
Fujiyama	4.07	0.95	13	9.3
Japan, general collection	3.46	1.31 highly significant	32	10.1 not significant
Standard error of means	—	±0.06	—	±0.30

(Devilla Nursery, Expt. No. 2 of 1951)

European Larch

The International Larch Provenance Experiments, planted in 1946 at Savernake and certain forests along the Welsh marches, suffered rather severely during 1952 from insect attack, *Argyresthia laevigatella* (the shoot borer moth),

Coleophora laricella (the leaf-miner moth) and the aphid *Adelges viridis* being the chief culprits. An attempt was made to assess the relative damage sustained by the various provenances. While no strains exhibited immunity to any of the pests, in general the most vigorous provenances sustained the least damage, though there were individual exceptions. Japanese larch showed significantly lower infestations of *Adelges* and shoot borer than did strains of European larch at most centres, but it was not noticeably more resistant to leaf miner.

Beech

A beech provenance experiment was laid out in the Latimer section of Wendover Forest, Buckinghamshire. This includes beech from Belgium, Holland, Germany, Czechoslovakia, Denmark, France and Austria, foreign origins all having been selected by foresters in the countries concerned as representative of good beech growing regions and sometimes of distinguished individual stands. In addition, the experiment includes beech from some of the best known English stands on the Cotswolds and South Downs, and it also includes progeny from the Chiltern woods at Watlington, where the beech are noticeably poor in both form and vigour. It has been suggested that Chiltern beech may have been degraded owing to adverse selection in the past, and this lot may provide some evidence on this hypothesis.

Adjacent to this experiment is a progeny trial of individual parent trees selected by the Geneticist from a number of the best English stands.

Scots Pine

The new experiments on the west coast of Scotland using different provenances of Scots pine, established both by intensive ground preparation plus phosphate and by simple notching with no manure, were successfully set out. These experiments were designed, as explained in last year's report, to test the resistance of different provenances to climatic defoliation near the western seas. At the end of the season there were significant differences in the percentages of plants with yellow needles. The yellowing was less in the plots planted with more intensive ground preparation and phosphate. The yellowing was also significantly less in some of the provenances, but this was probably partly due to differences in the size of the plants and may not prove to be an inherent characteristic.

REFERENCES

Bartlett, G.—"A Caithness Forestry Experiment"—*Scottish Agriculture* 1953, XXXIII(1), p. 33.

Robak, 1951.—On the connection between climatical damages and lethal attack by *Polyporous annosus* Fr. on plants and smaller trees of conifers in the planting area Hetlandsfelt. *Meddelelse Nr.* 27. *Vestlandets forstlige Forsoksstation, Bergen.*

Venables, I.S.T. and Venables, U.M.—"A Shetland Bird Population—Kergord Plantations". *Journ. Animal Ecol.* 1948, 17(1) p. 66.

Weatherell, J.—"The Checking of Forest Trees by Heather", *Forestry* XXVI(1) 1953.

RHODODENDRON PONTICUM IN BRITISH WOODLANDS

By J. M. B. BROWN
Forest Ecologist

Rhododendron ponticum L, which was introduced to Britain as an ornamental shrub in 1763, has become thoroughly naturalised, especially on sandy and peaty soils, and large areas of woodland have been colonised from planted ornamental avenues and shrubberies. The dense masses of rhododendrons, which develop in this way in favourable conditions, stifle any natural regeneration of trees and may greatly increase the difficulty and cost of artificial reforestation of cut-over stands. In view of the importance of *Rhododendron ponticum* (and, to a much less degree, of certain other ornamental shrubs, such as the cherry laurel, *Prunus laurocerasus*,) to the restocking of derelict and cut-over woodlands, an investigation of the distribution and ecology of *R. ponticum* has been undertaken.

Some of the aspects of rhododendron ecology which it is proposed to study are:—

(1) The production and dispersal of seeds.
(2) The influence of shade on germination of seed and on survival and growth of seedlings.
(3) Drought resistance in the seedling stage.
(4) The extent and manner of production of fresh shoots from stump or roots after cutting, burning or poisoning.
(5) The influence of winter cold and of spring and autumn frost.
(6) The relation between the growth of *R. ponticum* and soil reaction and nutrients.

Preliminary observations on some of these points may be summarised. The seeds are exceedingly minute, one gram yielding about 16,000, equivalent to 7 million seeds in one pound. Though not conspicuously winged or plumed, they possess a short frill at either end and may travel considerable distances in the wind. Dispersal for a distance of 50 feet (15 m.) has been recorded in open woodland and for a distance of over 150 feet (nearly 50 m.) from bushes 12 feet tall in favourable conditions in the open. This latter record is in good agreement with the calculated potential dispersal based on the rate of fall in still air (nearly one metre per second). In closed woodland, dissemination over distances of more than a few feet is probably uncommon. Seed dispersal is evidently the means by which *Rhododendron ponticum* spreads over new ground, whereas vegetative spread by layering is mainly of importance in increasing the ground cover of established colonies. Germination of seeds may take place in the dark, but with considerable delay as compared with seeds germinating in diffuse light. There is some evidence that germination is much delayed or wholly or partly inhibited in the open, but the factors at work have not been fully elucidated. In nature small seedlings of *Rhododendron ponticum* are almost always found on bare ground, but in the partial shade provided by the parent bushes, trees, tall heather, or ditch banks. Ditches often appear to provide channels of rhododendron dispersal. Young seedlings

have not so far been recorded under dense canopy of evergreen conifers, even where seed sources are near at hand. In relation to observations on the shade tolerance of rhododendron, some records have been made of the percentage of daylight which a Douglas fir canopy intercepts.

Rhododendron ponticum produces coppice shoots with great freedom and when the top is cut, burnt or destroyed by chemicals, many fresh sprouts are usually produced from the base. Root sucker shoots arise also under these conditions, and buried fragments may produce sprouts.

Autumn frosts appear to be damaging in some years on unprotected sites. No information has been obtained about winter cold in relation to *R. ponticum* survival and spread in Britain, but a temperature of 25°F(—4°C) maintained for 16 hours killed foliage and unopened buds of potted plants. The late opening of the buds in spring affords sufficient protection against spring frosts in most years.

In these ecological investigations of *Rhododendron ponticum* close contact is maintained with work on arboricides and mechanical means of destruction.

SURVEY OF TREE GROWTH ON COLLIERY SPOIL HEAPS

By R. F. WOOD and J. V. THIRGOOD
Silviculturists

This is a summary report on a survey of colliery spoil heaps undertaken by the Research Branch to obtain information on the possibilities of tree growth on this type of waste; a fuller report is being prepared.

All English, Scottish and Welsh coalfields with known plantations were visited, and it is thought that all existing plantations on spoil heaps were examined. In these coalfields all heaps which were reported to be carrying natural woody vegetation were also examined, and representative bare heaps were visited.

In all, over 200 sites were examined, some 90 of which were completely tree covered, either by plantation or natural growth. The relevant British and foreign literature has been surveyed.

Characters of Colliery Spoil Heaps

Constitution

Whilst the constitution of spoil heaps is dependent on a number of factors, it is usually dominated by argillaceous materials, shales and mudstones. Other common but lesser constituents are sandstones, boiler and furnace waste, slack coal and washery material. Naturally the constitution varies both regionally and locally, but in the main the properties of the shales and mudstones give the colliery spoil heap its special character. These materials weather rather rapidly, the mudstones breaking down to small cuboid fragments and the shales to little flakes. The resulting 'soils' are clayey in nature, and this may be accentuated by the presence of fire clay or ganister.

The proportion of actual coal present has varied greatly with the method of working. Slack coal accentuates the risk of combustion which is also related to the nature of the shales.

Much miscellaneous waste such as ashes and clinker finds its way to the colliery spoil heap, usually without modifying its main characteristics.

Washery waste is becoming a more important constituent and may be encountered as single heaps. It is tipped as a wet sludge of fine particles, and is distinguishable rather on the grounds of its unpleasant physical characteristics than on its basic composition.

In some coalfields about half the spoil heaps are burned, partially or completely. Typically, burning reduces the main constituents to a fine powder with many soft flaking shale fragments and lumps of fired stone. Massive concretions may also occur.

Configuration

The size and the shape of spoil heaps are determined by the methods of tipping in practice at the time. Somewhat arbitrarily, they can be classified on the following lines.

Low Medium mounds—Including the 'Hill and Hollow' formation of the older exposed coalfields and typical of South Staffordshire; the maximum height above soil level not exceeding 50 feet and often about 10 feet. Often a series of low undulations, with waterlogging in the low places, or irregular plateaux with numerous small hummocks. The tops are often flattened, and usually occupy a greater area than the sloping sides.

Isolated low mounds are also common.

High mounds and flat topped cones. Ranging in height from 50 to 200 feet or more. Generally single mounds with a plateau-like top, often with many minor hummocks.

Cones. Modern mechanical tipping practices give rise to high cones often exceeding 200 feet in height. Most of these seen were still in use. Many are on fire.

Ridges. Tipping by tramway or aerial cable may arrange the spoil in long ridges; the crest is sharper when the latter process is used.

Stability, Erosion and Weathering

A degree of stability is usually reached within two years after the cessation of tipping. There may, however, be a good deal of surface movement which is sufficient to prevent the establishment of natural vegetation *after* the heap is stable enough to plant. Severe gullying may occur on heaps of particularly fine material (such as washery waste). High plateau-like heaps often gully where water collected on the top finds a course over the edge. Whilst special measures may have to be taken, in general, instability of coal waste heaps will not be an important factor for planting of trees.

Weathering of the typical spoil material takes place rapidly, but unless vegetative cover is present much weathered material is lost. Under vegetation, particularly tree growth, soils quickly form. Spoil heap soils under tree cover may show little apparent sign of their origin after 80 years. Soils form most easily on the level and on gentle and lower slopes.

Moisture Conditions

Spoil heaps are surprisingly moist, particularly those consisting largely of unburnt shales and mudstones. They are by no means the arid sites one might well suppose them to be. To some extent the configuration and topography of the heaps affects the moisture of the material, but in general, lack of moisture does not appear to be an important factor. The surface layers of

heaps may dry out and prevent the establishment of natural vegetation where moisture conditions a few inches down are maintained at a sufficient level to permit the establishment of planted trees. Burned heaps may in general provide drier surface conditions than unburned heaps. The old 'hill and hollow' formations often show impeded drainage in the hollows.

Fertility

There is little evidence that colliery spoil heaps are infertile sites. The main constituents can produce quite fertile soils, which may have physical drawbacks but have certainly a reasonable nutrient status.

The reaction of fresh spoil is usually alkaline or near alkaline, but on weathering it becomes more acid. There is some suggestion that this process proceeds more slowly under woody vegetation than under herbaceous growth or in bare conditions, but the variation between individual heaps makes it difficult to detect any clear trend. The effect of burning on fertility is not clear; it certainly does not seem to reduce the fertility of the site to any serious extent.

Some cases of what appeared to be toxicity were seen. They seemed to be connected with a high degree of acidity, perhaps brought about by the oxidation of sulphur compounds. Such cases were relatively uncommon and usually confined to small patches.

Other Factors

All heaps will have higher exposure than that normal for the district, (which is of course very variable). The exposure factor may well become limiting on the higher slopes of large conical heaps, and preclude the development of woody growth of any stature.

The risk of combustion is another problem; it is obviously related to the content of carbonaceous material; in certain coalfields it appears the rule for heaps to ignite, and it may occur after very long intervals. The risks must obviously be kept in mind but can only be assessed locally. Heaps have been known to catch fire and burn out after thriving woodland has been established on them.

High surface temperatures on dark coloured spoil due to insolation may act as a contributory factor in delaying the establishment of natural vegetation, but this is of less importance to planted stock.

The General Environment

The general conditions of the locality are often far more important to tree growth than any factors which are peculiar to the waste heap.

In a rural coalfield, a much wider selection of species is possible than in a smoky industrial area, where only a few broadleaved species can be considered. Also the problems of protection may not differ substantially from those in any other small forestry project in the vicinity. But in crowded industrial areas the local population has often been the chief enemy of the plantations.

The regional climate is undoubtedly of importance. Fewer species are likely to grow satisfactorily in the North than in the South-west. Dryness in heaps will be accentuated by the lesser rainfall of the East. Highly exposed heaps will be worse in windy regions. These considerations will usually reduce the choice of species rather than rule out planting.

Natural Vegetation

The succession of vegetation on coal heaps was studied and it would seem that the onset of natural vegetation is often much delayed by purely surface

conditions, and that a vegetative cover is no guide to the earliest period at which tree growth can be established.

In course of time, not usually before the thirtieth year, some woody vegetation may be established naturally, and its type and behaviour may give some guide to choice of species for planting. Hawthorn is common on the heavier spoils, oak, ash and sycamore appearing later. Lighter spoils and particularly burned heaps, appear to favour gorse and birch.

Plantations

A number of plantations have been established in various parts of the country, mainly during the last fifty years. They do not include all possible species or cover all types of spoil heap, and the neglect or premature destruction of many has further restricted the evidence from this source. However, during the survey hardly a single case was encountered of complete failure to establish tree growth. Exceptions are mainly provided by the over-optimistic use of ornamental trees or shrubs.

It appears that some of the more difficult sites have as yet not been attempted. There has been little if any planting on the upper slopes of high conical heaps, and no planting of pure washery waste heaps was encountered. However, plantations were seen in many diverse localities; Somerset, the Dean, South Wales, the Black Country, Durham, Lancashire and the Lothians all providing examples.

Of pioneer efforts in this field, the work of the Midland Re-afforestation Association during the period 1903-24 in the Black Country should be mentioned. Whilst few of their plantations now exist, they provided valuable evidence on the possibilities of tree growth on spoil heaps in a smoke-polluted neighbourhood, and incidentally of the destructive proclivities of the local population.

Highly successful plantations were made in the North Somerset coalfield mostly during the period 1921-30, in Durham, near St. Helens, Auckland, during the 1930's, and in the Dean from the early 1920's, to mention a few only of the localities where work has been done on some scale. Plantations have succeeded equally well on both burned and unburned heaps.

Choice of Species

A number of conifers have done very well in rural coalfields, notably Scots pine, Corsican pine, Austrian pine, European and Japanese larch. Conifers have not succeeded in industrial neighbourhoods. Many broadleaved species have succeeded and indeed the heavier, near neutral, spoils should be well suited to broadleaved species.

In the smoke polluted atmosphere of the Black Country, common alder, wych elm, sycamore, ash, false acacia, rowan and hawthorn have all been recorded as attaining satisfactory stature. Alders seem to have been particularly valuable in the Black Country plantations on the sticky grey clay from weathered shale. Grey alder (*Alnus incana*) has succeeded very well on one spoil heap in the Forest of Dean.

To generalise, regional conditions—local climate, exposure, smoke pollution, etc. will dictate the *initial* choice of species; the special characters of the heaps may further restrict the choice in that the burned, the less clayey, and the older, often grass-covered and more acid heaps, are more suited to conifers, and perhaps to birch and alder, than to the more demanding broadleaved species.

Methods of Establishment

These have included special measures such as the use of very large stock and the addition of imported soil. In general, those measures have not been more successful than straightforward planting with normal sized stock. Nor does there appear to be any advantage in levelling the heaps.

General Comments

Since the existing plantations have by no means covered all the possible combinations of conditions to be met with in the coalfields, and since relatively few have been managed to bring out their full possibilities, it is unsafe to generalise about the economic capabilities of colliery waste sites. The impression is, however, that many, particularly in rural districts, are capable of producing respectable crops; and many more, in fact most, are capable of carrying tree growth, provided always that plantations can be protected from human depredation.

The principle points noted during the survey may be listed as follows:—

(1) Spoil heaps are usually reasonably fertile, and can also provide sufficient moisture to support tree growth.

(2) Difficulties due to instability and erosion are not usually excessive, though eroding heaps of very fine material such as washery waste may be impossible to plant without special measures to check gully formation.

(3) Actual toxicity is probably rare, and when it occurs, is often quite local in distribution.

(4) The very high modern conical bings may present special difficulties, largely due to exposure on the higher slopes.

(5) The choice of planting species is firstly governed by the local conditions, particularly by the factor of smoke pollution, which rules out most conifers. Secondly, there may be some further restriction to less demanding species on burned heaps, and older more acid heaps.

(6) Special measures such as levelling and the importation of soil are not usually warranted; nor is the use of extra large stock.

(7) Where there has been a failure to establish satisfactory plantations, accident and vandalism have been the main causes.

INVESTIGATIONS INTO DAMAGE BY THE GALE OF JANUARY 31st, 1953

By R. LINES
Assistant Silviculturist

First reports showed that damage to the woodlands of North East Scotland was of catastrophic proportions and warranted a detailed investigation. The gales of December 30th, 1951, and January 15th, 1952, had already caused concern and a procedure for such an investigation was ready. It should be appreciated that the great difficulty in investigating damage from wind is that the factors influencing windblow are so various, and their relative importance so little known, that reports from different observers will tend to lay stress

on different factors, and so perhaps obscure a possible overall conclusion. It was therefore decided that the investigation should be carried out by recording a comprehensive range of factors in as many blown woods as possible.

Field Work

The method of investigation used was first to discover where the main areas of damage were located, and secondly to visit the particular sites to record the details. Notes were made on a prepared form covering twenty-four different factors of the site and crop. These included species, age, height, spacing, crown shape and size, extent of rooting, previous thinning treatment, drainage and site factors. The survey covered both private estates and Forestry Commission woods, more time being spent on the former because of their greater damage and range of age classes. At all stages local opinion was consulted and eye-witness reports sought.

Meteorological data and other information was obtained from the Meteorological Office. Close contact was kept with the University of Aberdeen, where a special study of wind-blow was also being carried out.

Preliminary Conclusion

Meteorology. Both in intensity and duration the gale was of an exceptional nature. In many places gusts of over 90 miles per hour undoubtedly occurred, but due to the lack of recording stations the only concrete figures for peak gusts are those of Kinloss, 98 m.p.h., Dyce in Aberdeenshire, 101 m.p.h. and Milltown near Lossiemouth, which registered the highest speed recorded in the area, of 107 m.p.h. When compared with peak wind speeds for previous gales they are in some cases the highest ever recorded for the particular station. Higher speeds were recorded elsewhere in the 1927 gale, but this was from the South West, whereas the present gale was from the unusual direction of North to North-west. The gale continued at strength for many hours. It was perhaps fortunate that the preceding month had been very dry.

Extent of the Damage. The damage was widespread, ranging from Caithness to Allerston in Yorkshire, but the main damage was concentrated to the east of a line drawn between Inverness and Arbroath. In general the gale appears to have been most severe in the eastern part of this region, though this is possibly correlated with the lack of shelter from the mountains.

The volume of timber blown has not been fully assessed even yet, but it is clear that more than 40 million cubic feet are down. About 85 per cent of this is coniferous and 15 per cent broadleaved species.

Factors Affecting the Damage

Species. Scots pine suffered badly, but it is the most commonly planted tree. Damage has also been severe in the spruces and in Douglas fir. Larch, leafless at the time, suffered less than adjacent Scots pine. Of the hardwoods, beech, again the common species, has suffered badly, overmature trees being particularly unstable. Oak was always more windfirm and sycamore even more so, but it was observed that in one place or another all species had blown, no matter what their age or treatment.

Rooting. It has been established that in this region shallow rooting of supposedly deep rooting species is common; but since many truly deep rooted trees were blown, the significance of this is problematical.

Exposure. Aspect was of primary importance, the greatest damage being on north slopes, but elevation and slope mattered little. Damage was also severe on the sides of valleys running with the wind.

Age and Height. One of the most striking features was the lack of damage in the younger crops. Very few crops under 35 feet in height suffered at all and damage up to 45 feet was slight. Above this height wholesale wind-blow was frequent. This is no doubt the principal reason why Forestry Commission losses were comparatively light.

Edge effects. These were often striking and emphasised the wind-firmness of edge trees and the danger of neglecting plantation margins. A single weakened edge tree may cause the fall of 50 inside trees. Funnel effects and damage due to gaps were frequent.

Wind-blow and Wind-break. The former predominated, especially in larch. Wind-break occurred most commonly in spruce crops on firm ground. It appears to depend on roothold, crown form and timber strength.

Thinning and Spacing. Many of the crops were, by modern standards, under-thinned, and it would be tempting to conclude that this hastened their downfall. The evidence from sample plots hardly bears this out, however, and it is clear that recently thinned woods are specially susceptible to wind.

When the results of the first survey were analysed it became obvious that more data were needed to establish some of the above points on a statistical basis. Accordingly, additional information is being recorded by Census parties at work in the wind-blown areas. This report is therefore of a preliminary nature, and a fuller record is being prepared.

SILVICULTURAL EXPERIMENTS ON POPLARS

By J. JOBLING
Assistant Silviculturist

The increasing interest in poplar cultivation in Great Britain has meant that requests for advice on choice of site, method of planting and so on, are becoming increasingly frequent. It was to meet this demand that the programme of experiments, described below, was begun.

Field Experiments Laid down in Forest Year 1951

The two experiments planted in 1951 provided useful information on planting treatments and the use of fertilizers, and it is now felt that the results obtained from them support two recommendations, made below, with regard to the establishment of poplars. In the establishment experiment, at Harling and Hockham in Thetford Chase, and in Alice Holt Forest, mulching repeated each year had a definite beneficial effect on height growth during the summer of 1952, while the fertilizer and mounding treatments applied only at the time of planting no longer had any appreciable effect. There has been no significant difference in behaviour between the four varieties used in this experiment, nor has it been possible to detect variations in 1952 between the different types of plant originally put in. It does seem, however, that the smaller types (one-year rooted cuttings, or one-year rooted cuttings cut back and transplanted for a further year) are the most satisfactory during the first two seasons of growth.

In the manurial experiment, which was carried out on four sites, nitrogen has continued to have a small, but appreciably beneficial effect on height

growth, whereas the effect of potash or phosphate was negligible. The effect of nitrogen however, was less noticeable in 1952 than in the preceding season.

It is evident nevertheless, that nitrogen, in the form of ammonium sulphate, applied during the first growing season to the soil surface in the region of the plant roots, is a promising treatment, and that mulching, if periodically renewed, is even more beneficial.

Field Experiments laid down in Forest Year 1952

Of the two experiments planted in 1952 to investigate the respective merits of mulching, cultivating and mounding around the trees at the time of planting, only one has so far yielded information of value. This is an establishment experiment at Harling, carried out on stumped one-year plants of *Populus serotina*, which has shown that plants which were either mounded or had received surface soil cultivation in the region of the roots, had height increases significantly greater than untreated plants, while the height increases of the mulched plants, though appreciable, were not significant. The healthiest plants were those which were either mulched or cultivated. The second experiment designed along similar lines, but carried out on *P. robusta*, at Drayton, in Rockingham forest, was valueless as regards the object of the experiment, but confirmed that this type of site—a thick grass vegetation over a heavy clay—is unsuitable for the establishment of poplars by any method. It is possible that the competing vegetation could be effectively eliminated by using a chemical weed killer.

The extension to the field in 1952 of an experiment started the previous year at the Forestry Commission nursery at Kennington, Oxford, in which the growth and survival of plants resulting from close and wide spaced cuttings are being compared, has given no clear results. Although the plants raised at comparatively wide spacings in the nursery were significantly taller than those raised at a normal, close spacing, when planted out at Harling there were no differences in either survival or height increase between the two during the growing season. Nor was it possible to detect any variations in behaviour between plants which had been root-pruned during the growing season in the nursery and those which had not been treated in this way. There was no difference in height growth between the two varieties used, clones of *P. robusta* and *P. serotina*. All the 210 trees initially planted survived to the end of the growing season, and there is some reason to believe that on better poplar sites one-year old nursery plants behave as well as older stock, such as one-year plants from cuttings, stumped and lined out for one or two years, which have normally been used for establishing plantations in Britain.

One of the most successful experiments laid down in 1952, was an investigation into the effect on poplars of heavily liming acid soil before planting. Of the two varieties used, *P. serotina erecta* showed the most favourable reactions, giving height increases in limed soil often four or five times as great as those in untreated soil. A clone of *P. trichocarpa*, the other variety used, behaved in a less remarkable manner, but gave results encouraging enough to suggest that work along similar lines might be continued on Balsam poplars, as well as on Black hybrids. As well as stimulating height growth, the presence of the lime vastly improved the health of the trees, as shown by the many large, dark green leaves on the trees in limed plots, and the fewer and smaller, yellow-green leaves on trees in unlimed plots. The quantity of lime applied generally raised the pH of the soil of the treated plots from about 4.2 to over 6.0.

A pilot experiment was started at Harling in Forest Year 1952 on pruning poplars with two-year-old tops at the time of planting. This indicates, so far,

that complete removal of all side branches, or reduction of such branches to short stubs, gives better growth in the first year after planting (though not better survival), than no pruning, or reduction of the crown volume by the complete removal of some branches only. The experiment was carried out on small numbers of plants of several varieties. Obviously it will need further assessment to see whether the heavily pruned trees continue to lead, and the experiment will probably require to be repeated on a larger scale. However, experiments on the use of one-year planting stock may render further work on pruning before planting unnecessary.

Field Experiments laid down in Forest Year 1953

During the current forest year six experiments have been laid down in the field. Investigations into the comparative effects of wide and close spacing of cuttings in the nursery, with and without root-pruning treatments during the growing season, as a possible means of raising suitable planting stock during a single season in the nursery, have been continued. At Harling, an experiment has been laid down, using 200 plants each of *P. serotina*, *P. serotina erecta*, *P. gelrica* and *P. robusta*, in which a comparison is being made of one-year-old rooted plants, raised from cuttings inserted at three different wide spacings in the nursery, and one-year plants from cuttings stumped and lined out for a second year, the normal age of planting stock. Details of the nursery treatments are given below.

The beneficial effects of nitrogen on poplars are being investigated further in an experiment planted at Harling, using 432 plants of *P. robusta*. Nitrogen, in the form of ammonium sulphate, is being applied at three levels, 4 oz., 10 oz., and 16 oz., to the soil surface in the region of the tree roots at two different times during the growing season. Depending on weather conditions, it is intended that the first application of fertilizer should be made at the beginning of July and the second at the beginning of August.

Work on the effects on poplar of liming acid soil has been extended, and an experiment designed to study the continued effect of applications of lime has been laid down at Harling (soil pH about 5.2) and at Auchencastle in Greskine Forest, Dumfries-shire, on grassland over a medium stony loam soil (pH 4.6 to 4.9). On each site 216 plants of *P. serotina erecta* are being used, and sufficient lime was applied to the soil surface in the treated plots, before planting, to raise the pH of the soil, theoretically, to about 7.0. While the effects of a single liming will be observed for the duration of the experiment, it is intended to make two further applications to certain plots, before the commencement of the third and the fifth growing seasons, so that the reaction of poplars to heavy additional applications of lime can also be studied.

In the past, a number of deaths, which have occurred during the first growing season in trial plots and experiments, have been attributed to the roots drying out during the period between lifting the plants in the nursery and heeling them in on the planting site. As journeys of two or three days are often required to transport the plants, some degree of drying out must occur even though every precaution is taken to keep the roots moist. It is not known, however, how much they can be dried without causing the subsequent death of the plant in the field. An experiment has therefore been laid down at Harling, using *P. gelrica*, in which plants have been exposed to drying winds, after lifting in the nursery, for periods of from one to sixteen days before being planted. For comparison, plants were heeled-in in moist soil for sixteen days, whilst others were planted immediately after lifting.

Attempts at establishing the aspen hybrid, *P. tremula* x *tremuloides*, on a wide variety of sites during the past three years, have not been very successful,

and it is believed that the age and type of plant used may not have been suitable. To investigate this problem an experiment has been planted in Oakley Inclosure, New Forest, in which a comparison is being made of five different types of plant, (stumped one-year seedlings, transplanted twice; stumped one-year seedlings, stumped after one year lined out and transplanted one year; three-year plants, transplanted twice; stumped one-plus-one transplants lined out for one year, and two-year rooted cuttings). In addition, half of each batch of plants, with the exception of the rooted cuttings, were stumped at the time of planting.

An experiment designed to compare the growth of poplars planted at different spacings has been laid down at Congham in Gaywood Forest, Norfolk, on a basic fen peat over clay. *P. serotina* is being used, and four spacings, 26 ft., 18.5 ft., 14.5 ft. and 8.0 ft. (8.0m., 5.6 m., 4.4 m. and 2.5 m.), are being compared. The duration of the experiment is expected to be at least thirty years, during which time it will be possible to study the volume production of individual trees and plantations, thinning yields, types of produce and its disposal, methods of thinning and the economics of wide and close spacing. The experiment covers about nine acres of ground and will use 2,006 trees, half of which have already been planted; the remainder will be planted in 1954.

Nursery Experiments laid down in Forest Year 1952

An investigation into the effect of length of cutting on survival and growth in the nursery was carried out at Kennington nursery. Six lengths of cutting ranging from 4 to 9 ins. were under observation. The whole length of the cutting was inserted in the soil at the time of planting. From the point of view of survival, cuttings from 5 to 9 ins. were satisfactory, and only cuttings 4 ins. in length gave poor results. The differences in height growth were noticeable throughout the range, and the heights of shoots from cuttings 4 to 6 ins. in length were appreciably less than the shoots from longer cuttings. There was little difference in height growth, however, from cuttings of 8 and 9 ins.

An experiment comparing the effects of wide and close spacing of cuttings, with and without root pruning, was carried out at Kennington nursery during the past season. Cuttings of *P. serotina*, *P. serotina erecta*, *P. gelrica* and *P. robusta*, were inserted at three different spacings, namely 18 in. x 18 in., 18 in. x 24 in. and 24 in. x 24 in. Certain plots received a root pruning treatment in August and others in September. The survival was very high for all treatments and varieties, and the few deaths were attributed mainly to the relatively dry soil conditions which prevailed after the September root pruning. More deaths occurred in *P. serotina* than in the other varieties. All the spacings used gave rise to particularly tall plants, which were more sturdy and vigorous than plants raised at a normal close spacing. Numerous fibrous roots developed on the severed tips after the August root pruning, but after the September pruning the formation of fibrous roots was much less marked.

An investigation in the Alice Holt woodland nursery on the growth of cuttings inserted in soils of varying acidity yielded no information of value. The cuttings were inserted in soils which had received doses of calcium hydroxide ranging in quantity from ½ lb. to 4 lbs. per sq. yd. and, although the season's growth was more vigorous on plants in the heavily limed plots, the many cuttings which failed made an accurate analysis of the results impossible.

A preliminary experiment on the use of chemical weed killers among rising one-year plants raised from cuttings, carried out at Dean Barn nursery, Buriton Forest, gave promising results. Seven different selective weedkillers were tested, and the spraying was carried out in May, and as a separate set of treat-

ments in September, when the poplars had put on about 6 ins. and 4 ft. height growth respectively. The spring applications, with the exception of 2,4-dichlorphenoxyethyl sulphate (S.E.S.) and isopropylphenyl carbamate (I.P.C.), caused extensive damage to the poplars, and in a few cases killed the trees outright. Only "tractor vaporising oil" (T.V.O.) and a "White spirit" mineral oil had any appreciable effect on the weed population four or five weeks after spraying. The autumn spraying caused little damage to the poplars, S.E.S. causing least injury, while the white spirit and di-nitro-secondary butylphenol (D.N.B.P.) gave the highest percentage weedkill of all treatments. The weed growth in this nursery is very vigorous, and consists mainly of *Sonchus* spp., *Ranunculus* spp., *Veronica, Senecio vulgaris* and *Lamium amplexicaule.*

VARIETAL TRIALS AND OTHER WORK ON POPLARS

By

T. R. PEACE, *Forest Pathologist* and J. JOBLING, *Assistant Silviculturist*

In addition to the silvicultural experiments on poplar, which are discussed above, and the work on poplar diseases, which is mentioned in the paper on the 'Control and Avoidance of Forest Tree Diseases' on page 62, a considerable amount of work has been carried out on other matters connected with poplars.

Varietal Trials

Trial Plots

The distribution between countries of the trial areas is shown below:

	Major Trials	*Minor Trials*
England	3	10
Scotland	4	—
Wales	1	1
Total	8	11

They range from Brahan Castle, north of Inverness, to Quantock in Somerset. No new trials were started during the year. Several, which had made poor growth at the beginning, showed a marked improvement during the summer of 1952.

Most of the trials are still too young to give any real results, but the varietal trial at Yardley in Northamptonshire, which was started before the war, was assessed at the end of 1952. The soil is a heavy intractable clay, and carries a thick cover of mixed coppice, brambles, etc. It is a marginal site for the growth of poplar, and hard to afforest with any kind of timber tree. The most interesting plots, each consisting of 36 trees, are so far those planted in 1937, 1938 and 1939. The best average height is 32.7 ft. (10.0m.) for *P. carrieri* (a form of *P. regenerata*) known unfortunately to be susceptible to bacterial canker; this is closely followed by *P. rubra* Poiret (near to *P. marilandica* but later in leaf), *P. laevigiata* (near *P. robusta*) and *P. berolinensis* R. The same four also lead in girth, though in this case *P. rubra* Poiret with 15.8 in. (0.37m)

is slightly superior to *P. carrieri*. Other clones which are now doing quite well are *P. marilandica* F., *P. robusta* PH, *P. regenerata* P and *P. canescens* O, *P. gelrica*, *P. charkowiensis* and a number of the Italian selections, particular Nos. 65 and 214, are coming on well in younger plots.

Of course, for poplars, growth here is relatively slow, and it is doubtful if the crop will repay the high costs of establishment. On the other hand it is now fairly certain that good poplar timber can be raised on such a site, and that some suppression of coppice—a most important point on such ground —will result. In the best plots suppression is just starting (the spacing of the plants is 16.5 ft. (5.0m.) each way), and it is noticeable that large crowned varieties such as *P. marilandica* or *P. rubra* Poiret do this much better than narrow crowned ones such as *P. berolinensis* or *P. robusta*.

The Varietal Collection

The collection contained 229 clones in November 1952, compared with 223 in November 1951. A large number of new clones were received during the winter of 1951-52, but a considerable number of the older clones were discarded, either because they appeared to have little promise in Great Britain or because of doubts as to their identity. A further 32 clones have been received since November, many of which are of varieties needed for the Populetum, but unlikely to be included in field trials.

The Populetum

An area of about 25 acres (10 hectares) of semi-derelict agricultural land in the immediate neighbourhood of the Research Station at Alice Holt, near Farnham in Surrey, has been procured for a populetum. It is intended that this should include individual trees of all available species and of the older hybrids. The newer hybrids will be represented by a selection of the main groups. The populetum will be in four blocks, the largest of which will probably house clones of *P. nigra*, *P. deltoides* and *P. euramericana*. Planting of one small area with varieties of *P. trichocarpa*, *P. tacamahaca* and hybrids between them has been started.

Miscellaneous Varietal Experiments

We have still been unable to get a satisfactory site in an exposed position for a line trial of poplar varieties for resistance to wind. No clear results emerged from the first year's measurements on the poplars planted close to a wall. They have now been cut back to ground level, so that all subsequent growth will take place under conditions of one-sided light. It is hoped that this will show more clearly which are geotropic and which heliotropic.

Systematy

Mr. P. G. Beak of the Commonwealth Forestry Bureau, Oxford, continued his studies, particularly on the *P. berolinensis* group and on the Asiatic members of the sections *Tacamahaca* and *Leucoides*. He has again given invaluable help to the Research Branch by his identification of poplar material. Much of the information given on systematy in the "List of Poplars in the Possession of the Forestry Commission Research Branch—November 1952", a mimeographed document circulated to research workers on poplar, originated from Mr. Beak, who made a detailed inspection of the Research Branch collection in the summer of 1952.

Visits

Mr. T. R. Peace attended the sixth session of the International Poplar Commission in Italy and the subsequent excursions. By the kindness of Professor Piccarolo a useful day was spent at the poplar research station at Casale Monferrato in Italy, where the selection, rather than breeding, of poplars has reached an advanced stage.

In September, by courtesy of the Ministry of Agriculture of Northern Ireland, three days were spent in visiting poplar areas there. Identification is difficult at that time of year, but as far as could be judged no unusual varieties were encountered. Growth of *P. euramericana* was rather disappointing, possibly the result of the cool moist climate. This may be another area where a canker resistant clone of *P. trichocarpa* or a Balsam hybrid might be of value. One particularly fine stand of *P. canescens* was seen at Loughall, and cuttings have been received from this, so that a stock can be raised for inclusion in our trials.

Distribution of Cuttings

During the forest year 642 cuttings, of a wide variety of clones, were sent to persons in Cyprus, Holland, Hungary, South Africa, Southern Rhodesia, Sweden, Switzerland and Syria, and 148 cuttings of non-standard clones were sent to persons in Great Britain. These figures show an increase on last year's requests from abroad, but a decrease in the number sent to interested people at home.

For the fifth season cuttings of four certified poplar varieties have been distributed to private estates, trade nurseries and Forestry Commission nurseries. *P. eugenei*, which has been added to this list of "standard" varieties, has been distributed in limited quantity, and it is hoped that increased supplies will be available in future years. The actual numbers of cuttings distributed are given in Table 16 below, with comparable figures for the past two seasons.

DISTRIBUTION OF POPLAR CUTTINGS

Table 16

	P. serotina			P. serotina erecta (narrow crowned variety)			P. gelrica			P. robusta			P. eugenei		
	1953	1952	1951	1953	1952	1951	1953	1952	1951	1953	1952	1951	1953	1952	1951
Forestry Commission	3809	1590	1735	5459	1450	1610	4360	1500	1610	4458	1450	705	250	—	—
Private Estates and Trade	2950	2259	3820	1900	1597	3275	2975	1647	2310	3900	2607	4655	—	—	—
Total	6759	3849	5555	7359	3047	4885	7335	3147	3920	8358	4057	5360	250	—	—

In addition, 2,200 cuttings of *P. serotina* have been sent to Northern Ireland for use in a spacing experiment by the Forest Service, and 1,500 other cuttings of the "standard" varieties have been sent to Eire, Northern Ireland, India and Southern Rhodesia for use by the Forestry Departments. All cuttings sent abroad have been surface-sterilized before despatch.

FOREST GENETICS

By J. D. MATTHEWS
Forest Geneticist

Survey of Seed Sources

The location of suitable seed sources for current and future planting programmes continued during the year. The survey of Scotland, covering all species in common use, was extended to the counties of Caithness, Inverness, Nairn, Ross and Cromarty and Sutherland. Some surveying was also done in the north of Argyll.

Over 100 woodlands were assessed and classified as suitable (A or Plus and B or Normal), or unsuitable (C or Minus) for seed collection. The classification B+ was used for borderline cases where the accumulation of further knowledge is likely to raise the rating to A or Plus.

The area of plus and normal seed stands in the counties mentioned above (i.e. in the North Conservancy of Scotland) amounts to almost 1,500 acres. Scots pine seed sources account for two-thirds of the total, while European larch, Douglas fir, Norway spruce and Sitka spruce together make up most of the remaining third.

Selection of Parents for Tree Breeding

The selection and propagation of a series of outstanding phenotypes (Plus trees) for use in breeding improved strains of the major forest tree species, continued. The number of plus trees of all species which have been marked and recorded is now 624.

One hundred and forty-seven plus trees, the majority being Scots pines, were blown down during the storm on 31st January, 1953, which caused such widespread damage to woodlands in North-East Scotland. Scions for grafting and seed have been collected from these and from other fallen trees in an effort to perpetuate the most successful strains. One hundred and sixty-two Scots pines and thirty-nine European larches were propagated during the spring of 1953.

Vegetative Propagation: The Rooting of Cuttings

This general heading of vegetative propagation includes grafting, budding, the rooting of cuttings and layering. A short summary of the aims and methods of grafting was given in the Report on Forest Research for 1951. A description of the progress made with the rooting of cuttings now follows.

Propagation by dormant and summerwood cuttings is used to bring the breeding material together into a convenient place, to test the genotype of the selected plus trees, and to reproduce sterile hybrids or other valuable individuals which cannot readily be raised from seed. At Alice Holt the method is restricted at present to species such as *Thuja plicata* and *Sequoia sempervirens*, which can be rooted relatively easily; but research into the striking of cuttings of mature trees of more difficult subjects, such as the pines and larches, is in progress.

Successful rooting of cuttings is dependent upon the origin of the cuttings, the treatment before insertion in the propagating bed, and the propagation conditions employed. The after-care of the rooted cuttings is also of import-

ance—the object being the production of vigorous, well-balanced plants capable of surviving planting in the forest.

Origin of Cuttings

With many tree species, cuttings taken from young specimens strike more readily than those obtained from older individuals. This has been noticeable at Alice Holt in experiments with Scots pine, European larch and Sitka spruce. In *Thuja plicata* and *Sequoia sempervirens* the effects of age have been less pronounced, but cuttings from seventy and eighty-year-old trees of *Sequoia* have rooted more slowly and have developed fewer and more weakly roots than cuttings from ten-year-old trees.

Some evidence of variation in the rooting capacity of individual trees has appeared in *Sequoia sempervirens*. Cuttings from one of ten trees of *Sequoia sempervirens* of similar age, growing on the same site, began to root sixty days after insertion, during which time cuttings from some of the other trees had hardly begun to produce callous tissue at their bases. A forty-year-old tree from Alice Holt Forest has consistently failed to strike from more than a very few cuttings taken from the lower, middle and upper parts of the crown. Coppice shoots from this tree have, however, rooted with up to fifty per cent success, but rather slowly, taking about two hundred days.

In × *Cupressocyparis leylandii* and *Sequoia sempervirens* cuttings taken from the lower parts of the crowns of adult trees have rooted better than those from the upper parts. For the same two species, and also for Sitka spruce, partially-shaded lateral shoots have rooted more easily than terminal shoots growing in stronger light conditions. The more vigorous cuttings are preferable, however, because of the radial habit of buds and foliage, and their capacity to produce a stronger root system. Weakly shoots of Sitka spruce, *Sequoia sempervirens* and European larch tend to assume a prostrate habit and do not make good plants without being staked or stumped-back, or both. Difficulties of this nature often arise when propagating from the older plus trees. Stool beds are now being formed at Alice Holt and Grizedale with the first batches of rooted cuttings from plus trees, and the stool beds will be used as the sources of material for subsequent large scale propagation.

Experience so far indicates that dormant cuttings can be taken with a small heel of older wood but summerwood cuttings of × *Cupressocyparis leylandii*, *Sequoia sempervirens*, Sitka spruce and beech are best taken without a heel. The most practicable size for both dormant and summerwood cuttings for most of the species tested has been from four to six inches.

The time at which cuttings should be taken cannot be related to the calendar in more than a general way. Good results have been obtained with cuttings of × *Cupressocyparis leylandii* and *Sequoia sempervirens* taken just before shoot growth commences in spring, that is, generally in early or mid-March. Summerwood cuttings should be taken as soon as the new growth becomes sturdy enough to stand without support, i.e. late June and early July for most species. Earliness is particularly important with deciduous species such as European larch, × *Larix eurolepis*, London plane, beech and *Metasequoia*. A good root system and well ripened shoot is vital if the cuttings are to survive the winter.

Treatment of Cuttings before insertion in the Propagating Bed

The parent trees which are propagated to further a breeding programme are generally widely scattered and considerable trouble is taken to reduce the time elapsing between collection and insertion of the cuttings. Branches eighteen inches long are packed in moist sphagnum or granulated peat, sur-

rounded by a framework of mouse netting and covered with hessian, labelled, and sent by post. On arrival at Alice Holt the cuttings are immediately inserted into the prepared bed.

The use of growth substances has been extensively tested. The use of the concentrated dip method of applying indolyl-butyric acid recommended by Mr. R. J. Garner of the East Malling Research Station, Kent, is now standard practise at Alice Holt. The concentration of one milligram of the growth substance per one c.c. of fifty per cent alcohol has increased the speed of rooting and the number of roots developed by cuttings of × *Cupressocyparis leylandii*, × *Larix eurolepis*, European larch, *Metasequoia* and Sitka spruce. The method consists of dipping the basal half inch of the cutting momentarily in the solution, allowing the solution to dry, and inserting the treated cutting with the aid of a dibber.

Propagating Conditions

Four types of propagating frame are under test at Alice Holt, a number of different rooting media are being compared, and the effects of electrical heating of these media are being studied. The layout is such that the behaviour of cuttings of a given species can be observed under a wide variety of temperature, moisture and light conditions.

Two propagating frames of equal size, sited close together, have been built for studies of the effects of rooting medium, electrical bottom heating, and later of artificial lighting, on the rooting of cuttings of the more difficult species. Two commercial frames, one span-roofed and nine feet wide, the other lean-to and 4½ feet wide, are used for the development of large scale methods of propagation. More recently a new type of frame incorporating sub-irrigation has been tried. The water is carried to the rooting medium by means of a glass wool wick supported by a metal grid. A span-roofed timber frame and a large barn cloche are used for hardening-off cuttings rooted in the propagating frames.

Some interesting results have been obtained from comparative trials of four rooting media used singly and in various mixtures. The media are exfoliated vermiculite (a micaceous mineral expanded by heating), quartz sand, pumice and Sorbex granulated peat.

Cuttings of *Sequoia sempervirens* have been rooted in sixteen media in the unheated span-roofed frame, and in twelve media in the unheated propagating frame. In both frames, sand and pumice used alone gave significantly smaller numbers of rooted cuttings than most of the other media. There were no significant differences between the number of cuttings rooted in the other media, but mixtures of peat and vermiculite gave better results than mixtures containing more than 50 per cent of sand or pumice. The mixture of 75 per cent peat and 25 per cent vermiculite gave high numbers of rooted cuttings in both frames.

The advantages of electrical warming of the rooting medium have been demonstrated since 1950, when the first experiments with a low tension bare wire system were commenced. A standard loading of seven to nine watts per square foot of frame is now employed, and this is sufficient to maintain media temperatures of up to seventy degrees Fahrenheit in propagation frames. The system, which includes thermostatic control, has proved reliable and easy to operate. The speed of rooting of × *Cupressocyparis leylandii* and *Sequoia sempervirens* has been substantially increased with heat. A combination of electrical soil warming and sub-irrigation is to be tested as soon as possible.

Aftercare of Rooted Cuttings

Investigations under this heading are at an early stage and no definite results

can be reported. The development of the various types of root systems produced by cuttings is being studied, and a number of hardening-off and transplanting sequences from frame to open nursery are under test. Rooted cuttings are also being stumped back at different stages of their development.

The Flowering and Fruit Production of Forest Trees

The general observations on the flowering and fruit production of the major species were continued. Mr. Mitchell has recorded the times of flowering and leafing-out of trees growing near to Alice Holt during the spring of 1953. More general observations have also been made further afield in parts of England and Scotland. Details of progress during the year ending in March, 1953, are given below by species.

Corsican Pine

Flowering and Cone Production. The register of seed sources is now complete. The work now consists of studying methods of increasing the seed production from the best stands. Observations on plantations throughout the country indicate that, in Britain, Corsican pine generally commences flowering and cone production between the twentieth and twenty-fifth year after planting. Open grown trees often commence flowering at a slightly earlier age than those in plantations, and well-grown dominant trees within plantations bear flowers before less vigorous trees in the same crop. Trees in the South of England produce flowers at an earlier age than those growing in the Midlands and North of England or in Scotland.

Between twenty-five and thirty years of age, flowering and cone production is limited and sporadic; but from the thirtieth year, in the East and South-East of England, yields of between one and three pounds of seed per acre can be expected in good years. A Corsican pine seed tree must be in good health if it is to produce a good crop of well filled, viable seed. The length of time elapsing before a seed tree is again ready to produce a good crop of flower buds is shortest on the better Corsican pine sites and where the crown has ample space for a speedy replacement of the foliage lost to reproduction. Favourable weather is the next essential, and it appears that a warmer, sunnier and dryer-than-average summer is a necessary prelude to renewed flowering and cone production. There were good cone crops in East and South-East England in the autumns of 1945, 1947, 1949 and 1951. These evidently had their origins in the warm, dry, sunny weather in these districts during the summers of 1943, 1945, 1947 and 1949.

Stimulation of Flowering and Cone Production. An analysis of the cone crops produced in 1949 and 1951 revealed that the crops were heaviest in East Anglia, intermediate in South-East England, and poorest in the Midlands. There are a number of very good stands in the last named area, and one of the best blocks of Corsican pine in the country is situated in the Carburton section of Clipstone Forest, Nottinghamshire. It was decided to use part of a twenty-six year-old plantation in this forest for a trial of methods of increasing the production of cones in the Midlands. Inorganic nutrients have been applied to the forest floor, and partial girdling of the stems of trees of four girth classes is also included in the experiment.

An experimental seed orchard has been established in Tangham Nursery, Rendlesham Forest, Suffolk, using grafts from spring 1952. The orchard contains clones of thirty-five plus trees and covers one acre. A trial of root-stocks, which compares the effects of rootstocks of five two-needled pine species on the growth and flower production of a single clone of Corsican pine, has also been planted at Rendlesham.

Beech

The number of plus trees which have been marked and recorded is now forty-two. Thirty-six of these have been propagated by grafting.

Two progeny trials were planted during the spring of 1953, one in Alice Holt Forest and the other at Latimer Woods, Wendover Forest, Buckinghamshire. In these trials the progeny from plus stands and from the free pollination of plus trees in this country are being compared with progeny from beech woodlands in many parts of Europe. A small experimental seed orchard of beech was planted at Rendlesham Forest, Suffolk, during the spring of 1953.

Larches

One hundred and seventy-nine plus trees of European larch and thirty-two of Japanese larch have been marked and recorded. A total of seventy plus trees of larch have been propagated by grafting.

The number of larch graftings made during the spring of 1953 at Grizedale, Lancashire, and Newton Nursery, Moray, will exceed 1,000. The bulk of the scion material came from wind blown trees in North-East Scotland, but scions of European and Japanese larch were received from the Horsholm Arboretum, Denmark. The study of the propagation of the larches from cuttings continued.

At Newton Nursery work continued on the establishment of the first seed orchard for the production of first generation hybrid larch ($\times$ *Larix eurolepis*). Preparations were also made for the planting of two more seed orchards for the production of seed of hybrid larch. One will be at Mabie Forest, Dumfrieshire, and the other at Drumtochty Forest, Kincardineshire.

Scots Pine

The total number of plus trees recorded is now 324. One hundred and ninety of these have been propagated by grafting.

Propagation by Grafting. The collection of scions from plus trees of Scots pine in East Scotland commenced on the 18th January, 1953. Grafting under glass was begun at Grizedale on the 20th January. After the gale of January 31st the original programme was enlarged, and attention was paid to the propagation of trees from ten plus stands in the Dee Valley and in Moray.

Ninety per cent of the grafts are being done in the open nursery, using one-plus-one and two-plus-one transplants as stocks. The outdoor propagation began on March 16th and took over two months to complete. The scions were kept in a cool store until required.

More than 2,000 grafts had been completed at the end of March, 1953, at Grizedale, Lancashire; Alice Holt and Bramshill, Hampshire; and Newton Nursery. The final total was more than 5,000.

Sitka spruce

The search for plus trees possessing superior growth vigour and form, hardiness to late frosts, and resistance to *Neomyzaphis* attack, continued.

The progeny arising from the free pollination of twenty plus trees have been planted out. Four sites have been selected, two at Kilmichael Forest, Argyll, and one each at Gwydyr and Clocaenog Forests in North Wales. Five plus trees are represented on all four sites, and the same standard origin (a general seed collection from Queen Charlotte Island, British Columbia) appears at each centre.

STUDIES OF GROWTH AND YIELD

By Dr. F. C. HUMMEL
Mensuration Officer

Sample Plots

A summary of the numbers of permanent sample plots established, remeasured and abandoned during the year is given in Table 17.

SAMPLE PLOTS, 1953

Table 17

	England	Scotland	Wales	Total
Plots in being 1st April, 1952	216	201	81	498
Plots established 1.4.52 to 31.3.53	47	15	7	69
Plots written off	2	15	1	18
Plots in being 31st March, 1953	261	201	87	549
Plots remeasured 1.4.52 to 31.3.53	93	52	Nil	145

Remeasurements—England 16 Complete, 77 Intermediate.
Remeasurements—Scotland 25 Complete, 27 Intermediate.

Of the 69 new plots, 47 are in England, 15 in Scotland and 7 in Wales. The large proportion of new plots in England is explained by the emphasis that is now being placed on broadleaved species. 19 of the new plots are broadleaved, and all of these are in England.

During the year losses from wind were serious. 15 plots had to be abandoned in Scotland, 2 in England and one in Wales.

Yield Tables and Volume Tables

The revision of the conifer yield tables was completed. They are to be published in the form of a bulletin which will describe in detail the methods used in preparing the tables, and give comparisons with yield tables from other countries. Meanwhile the tables themselves have been published as Forest Record 24, *Revised Yield Tables for Conifers in Great Britain.* (H.M.S.O. 1s. 3d.).

A volume table was for small hardwood trees. The previous volume tables for oak, beech and birch start at a breast height quarter girth of 6 inches. The new table caters for trees between 2½ and 6 inches breast height quarter girth, and it was found to be applicable to all the common broadleaved species in Britain*.

The last annual report referred to a study of the relationship between the volume of trees in a stand and their sectional areas at breast height; it also

* Forest Record 28. *Volume Table for Small Hardwood Trees,* H.M.S.O., 9d.

referred to a special kind of volume table, now termed a 'general tariff table', which was prepared as a result of this study. These tables are now used within the Forestry Commission, both for census purposes and estimating the volumes of thinnings after they have been marked, but before felling. A paper has been drafted for publication, which describes the underlying theory as well as the use of the tables in the field.

Work for Utilization Development Section

More work was done on basic mensurational data required by the Utilization Development Section. The investigation on the volume and yield of hazel coppice, referred to in last year's annual report, has been completed and the results have been written up. A similar investigation, on a smaller scale, has been carried out on Spanish chestnut. The next forest types to be investigated are oak scrub and coppice.

Census of Woodlands

A report was prepared and published, entitled *Hedgerow and Park Timber and Woods under Five Acres*, 1951. (Census Report No. 2, H.M.S.O., 5s.)

Field work was started on the revision of the main census. When the census of woodlands of 1947-49, which covered the whole of Great Britain, had been completed, it was the intention to carry out similar surveys at periodic intervals of 10 to 15 years. For various reasons, however, it has been found preferable to adopt a system of 'continuous' census revision, by which a limited number of counties, comprising about 7 to 10 per cent. of the total woodland area of the country, are resurveyed each year.

The new census embraces all woods irrespective of whether they are owned privately or by the state; and small woods and hedgerow and park timber are included as well as the larger woods of over five acres.

The revision was started in December 1952 and by March 1953 field work was in progress in Rutland, Huntingdon and Kincardineshire.

Other Work

The main items were the design and analysis of experiments for the various sections of the research branch, lectures and field demonstrations, forecasts of timber production for specific areas or for specified produce classes, and the answering of enquiries.

THE CONTROL AND AVOIDANCE OF FOREST TREE DISEASES

By T. R. PEACE
Forest Pathologist

Obviously the chief immediate aim of research work on diseases of trees is to find methods of preventing, or at any rate lessening, their ravages. Thus experiments on control or avoidance will be found at quite an early stage in any research project of this nature; these will have often been initiated long before the fundamental pathological make-up of the disease has been fully disclosed. For this reason a review of the present position in the control and

avoidance of disease can well present a picture, albeit a somewhat one-sided one, of the progress of research on forest tree diseases as a whole.

The inclusion of the word 'avoidance' in the title of this paper is deliberate, for although escape from many diseases is impossible, with others we are still able to find unaffected areas or sites, which can be used for the propagation or growth of susceptible trees.

The various means of control and avoidance of forest tree diseases are discussed under rather wide headings below. Naturally, in order to present a reasonably balanced account, research work done in past years at the Forestry Commission Research Station, and elsewhere by other workers, must needs be mentioned. Indeed, since the build-up of our knowledge of tree diseases is a slow and apparently almost endless business, the work of a year or two, presented alone, would appear suspended in mid-air and without proper foundation. Nevertheless particular stress has been laid on recent advances, and on work newly completed or now in progress in the Research Branch.

Quarantine Measures

In the past we have been prodigal in our importation of living trees, many of which have brought with them fungal and bacterial diseases. Had the present prohibition of import of the chief coniferous genera been in force over the last hundred years, we should probably have been spared at least one third of the diseases, which now afflict those trees. However, the introduction of this measure in 1933 recognized that there were still dangers against which defence was needed. Recent information suggests not only that this measure was justified, but also that grave dangers, against which measures must be taken, threaten some of our hardwoods.

Over the past few years the progress of *Endothia parasitica* (Chestnut Blight) in Italy and Switzerland; of *Chalara quercina* (Oak Wilt) in the United States, which is by American evidence also a threat to *Castanea*, and of "phloem necrosis" of elm (a virus disease), also in the United States, has been followed with interest and apprehension. In June 1952 a visit to Italy and the Tessin province of Switzerland made it possible to see something of the ravages of Chestnut Blight in those countries, and in one Italian valley west of Florence to compare the present position with that in 1948. The danger was considered great enough to necessitate the addition of *Castanea* and *Quercus* from any part of the world, and *Ulmus* from America, to the list of prohibited genera. This action has already been taken. *Endothia parasitica*, which produces spores profusely on the bark of chestnut and occasionally attacks oaks, though with much less virulence, appears to demand even more rigorous precautions. The behaviour of the disease in Southern Europe and in America makes it quite certain that strong measures ought to be taken to prevent its establishment in fresh areas, while American experience in the western states has indicated that spot outbreaks can be eradicated by resolute action.

Internal quarantine measures, on the other hand, are difficult to apply and uncertain in their outcome. In the case of two tree diseases, which are still with us, Elm Disease caused by *Ceratostomella ulmi* (first detected in 1927) and Sooty Bark of Sycamore associated with *Cryptostroma corticale* (first detected in 1945), attempted control by the eradication of diseased trees was contemplated in the early days. In the case of elm disease it is now quite certain that felling of diseased trees would have removed more elms than have been destroyed by the disease, great though its ravages have been. Although the disease still flares up in most years in one or more areas, it would seem that the general recommendations to remove dead, dying or badly disfigured elms are all that need be done.

The present position of the sycamore disease, as disclosed by a survey of known outbreaks made by Mr. H. Dowden in the summer of 1952, is that in most areas it has made practically no progress since 1950. This clearly indicates that any panic effort to remove all affected trees would not only have been premature, but would have resulted in the removal of a considerable number of slightly affected trees, which today have either recovered or are no worse. Nevertheless the original outbreak of this disease was very definitely alarming, and we certainly need to know more about it. In fact the pathogenicity of the fungus *Cryptostroma corticale*, which is invariably associated with it, has not yet been completely proved. It is refreshing to record that work on this disease has been started by Dr. N. O. Robertson and Mr. J. A. Townrow of the Botany School at Cambridge. A preliminary note on their work appears on page 118 of this Report.

There is nothing new to report on the one tree disease subject to internal legislation in Great Britain, the bacterial vascular disease of willow, generally known as 'Watermark Disease'. Eradication of diseased willows is still proceeding steadily in Essex under the direction of the Essex County Council, and also in Suffolk and Hertfordshire. But it has not yet proved possible to continue the much needed research into the means of spread and other aspects of the disease, or to record and analyse the data on eradication and subsequent reinvasion, which might be gleaned from the activities of the County Council. Only very general figures are available to indicate the success of the campaign.

Choice of Site

For a number of diseases it is still possible to select sites where attacks are unlikely to occur, or where the damage done is within the limits of toleration. A clear cut case of this kind is that of the rust fungus, *Melampsora pinitorqua*, harmful to Scots pine, with aspen poplar (*Populus tremula*) as secondary host. By the avoidance, in Scots pine planting, of sites where aspen occurs, the disease itself can be evaded.

But in most cases greater knowledge of site values, and particularly of their relation to the various diseases, is needed before we can make definite recommendations; while with several diseases increased knowledge of distribution has made the possibility of control by site avoidance much less feasible than was at first hoped. For instance, several outbreaks of the root disease of Chestnut (*Castanea*), caused by the fungus *Phytophthora* and generally known as 'Ink Disease', have been found in recent years on excellent deep well-drained loams; whereas, generally, there is an obvious tendency for it to occur mainly on somewhat heavy soils with wide differences between their summer and winter water content.

The rather prevalent dieback of Corsican pine, attributed in the past mainly to *Brunchorstia destruens*, but more probably due to a complex of fungi and natural factors; and the chlorotic dieback of certain conifers, notably Scots pine, on calcareous soils, appear to be associated with high elevation and high rainfall in the one case, and with high lime content in the other. Nevertheless it would be a pity to limit our planting of these valuable species to low and dry sites in the one case, and acid sites in the other. Much more work on site relationships is needed, before we can be dogmatic about these limitations. The poor behaviour of conifers on certain calcareous soils is not limited to Scots pine, and during the year severe dieback of Japanese larch, apparently attributable to this cause, was observed in a plantation on the Wiltshire Downs.

Two cases of chlorotic dieback of Norway spruce used for Christmas trees are under investigation. One might be partly due to calcareous conditions,

the other most certainly is not, the health of the trees being in some measure improved by dressings of lime.

The planting of that valuable tree the Weymouth pine, *Pinus strobus*, has been almost completely stopped by the threat of Blister Rust (*Cronartium ribicola*), which with *Ribes* (mainly blackcurrant) as secondary host, is capable of ruining otherwise promising plantations. Indeed so little *Pinus strobus* has been planted, that we have very little idea of its site range in Great Britain. It was suggested by Dr. Boyce of Yale that in more remote forest areas it should be possible to find relatively safe sites at least one-and-a-half miles from the nearest dwelling and therefore, generally, from the nearest currant bushes. In practice it has proved very difficult to find such sites, and when located they are usually places where, either on grounds of soil or exposure, one would hardly expect *P. strobus* to thrive. However, six such sites were selected during the summer of 1952 and have now been planted with small test blocks of pine; later, the nearest currant bushes will be examined for signs of infection. But it is obvious that we shall not be able to plant any large areas of pure Weymouth pine, in places well away from currant bushes, and it is proposed to test the possibilities of mixed plantations.

Choice of Variety

It is quite possible that choice of variety may become in forestry, as it has done in agriculture, one of the main lines of disease control. Recent advances in forest genetics, and the accompanying improvements in large scale vegetative propagation, make this much more likely. Even now there are several diseases, where choice of species, rather than of variety, offers a fruitful line of advance. For instance in the case of *Melampsora pinitorqua*, mentioned above, Corsican pine and Maritime pine can safely be planted in infected areas containing aspen; while not immune to the fungus, they are highly resistant.

With the root fungi *Armillaria mellea* and *Fomes annosus* there are wide differences in susceptibility between different tree species.

An investigation in the summer of 1952 into damage by fumes from brickworks to trees in south Bedfordshire, indicated that there were marked differences in susceptibility, oak, elm and sycamore, particularly the latter, suffering severe leaf injury, while ash was relatively unharmed. Unfortunately the older ash of these clay areas are subject to an unexplained dieback, possibly connected with root disease, so that widespread planting of ash as a roadside tree in places subject to fumes cannot always be recommended.

It is known that certain Asiatic chestnuts are resistant to Chestnut Blight, and it is therefore of some interest to discover how they behave in our climate. Most of the information is discouraging, mainly because of lack of hardiness ; though there is one place, the Royal Botanic Garden, Edinburgh, where one of the rarer chestnuts, *Castanea henryi*, is doing as well as our common chestnut, *C. sativa*. Large quantities of *C. crenata* were raised from seed and have been planted in a variety of sites in England and Scotland, while a smaller number of *C. mollissima*, raised from selected American seed, are to be planted at Bedgebury. The *C. henryi* already mentioned has been propagated by grafting.

Clonal work on disease resistance is more difficult, except with trees like poplar, where vegetative propagation is easy. Stocks of *Pinus strobus* clones selected in the United States for resistance to *Cronartium ribicola* are being gradually increased at the Research Station; while several trees of the Dutch elm selection Bea Schwarz, which is said to be resistant to Elm Disease, have been planted in a very heavily infected area on Sheppey Island, Kent.

Poplar clones are being tested for resistance to bacterial canker, by wound inoculation with bacterial slime. The results of the inoculations made in 1951 (assessed in 1952) were very satisfactory. The provisional deductions from these results, combined with those of previous years, have been circulated in a mimeographed 'List of Poplars in the Possession of the Forestry Commission Research Branch, November 1952'. They will not be published in full till further results are available. Up till 1951 inoculations had been made on established plants; but in 1952, following the method elaborated by Dr. K. A. Sabet at the Cambridge University Botany School, long cuttings were inoculated in the spring following insertion, at an isolated nursery at Mundford, Thetford Forest, Norfolk. In 1952, 1,280 plants of 145 clones were inoculated, these will be assessed in May 1953. In addition bacterial canker will be deliberately introduced into some of the varietal trial areas, by inoculating two trees in each clonal planting of sixteen. Results of these inoculations will be recorded, but information is also expected from possible subsequent natural infection. The poplars of various clones, which were planted among cankered suckers of *Populus candicans* at Parlington Park, Yorkshire, in the winter of 1951-52, have established themselves, but it is too early yet to expect natural infection.

These semi-natural infections may serve as an aid in the task of evaluating the significance of artificial inoculations. When the 'take' is good, as it was in 1951-52, many varieties are infected, which normally escape attack in nature. Very probably wound inoculation gives the bacterium a better chance. Certainly it does away with the necessity for a carrier, which, if it were an insect, might by discrimination between varieties for food purposes, itself have an influence on varietal attack. Clones which continually resist artificial infection can be regarded as resistant in the field; those which show continued high susceptibility can be regarded as susceptible in nature, or as trees to be used only with caution; but those in the middle group, which react to artificial infection erratically, or by constant moderate infection, give little indication of natural susceptibility.

Adaptation of Silvicultural Practices

The comparatively low return per acre per year, and the long term nature of a forest crop, make the standard agricultural methods of control, spraying, eradication, or change of crop, difficult or uneconomic. It is therefore desirable to find treatments which can be combined with and form part of normal silvicultural operations.

For instance experience over the past three years has shown that attack on newly planted poplars by the bark killing fungus *Dothichiza populea* occurs very largely around pruning wounds on large planting stock. The use of smaller and younger plants, which is also desirable on grounds of economy, appears to be a practical method of avoiding attack by this fungus. If large plants have to be used, summer pruning so that the wounds are partially healed, before the trees are lifted, seems to lessen infection.

Death of beeches has been widely reported from many areas, chiefly on the Downs and the Chilterns, accompanied by dying of the bark. Investigation of such cases has shown that some, if not all, of three factors are present—a thin freely-drained soil, an old crop, often over a hundred years of age, and a history of under-thinning leading probably to great competition among individuals in the stand. Observations on numbered plots in affected areas indicate that the progress of the disease is slow in the individual trees. *Cryptococcus fagi* is often present on such trees, but since diseased trees free from *Coccus* are also observed, it is unlikely that this insect is of primary importance.

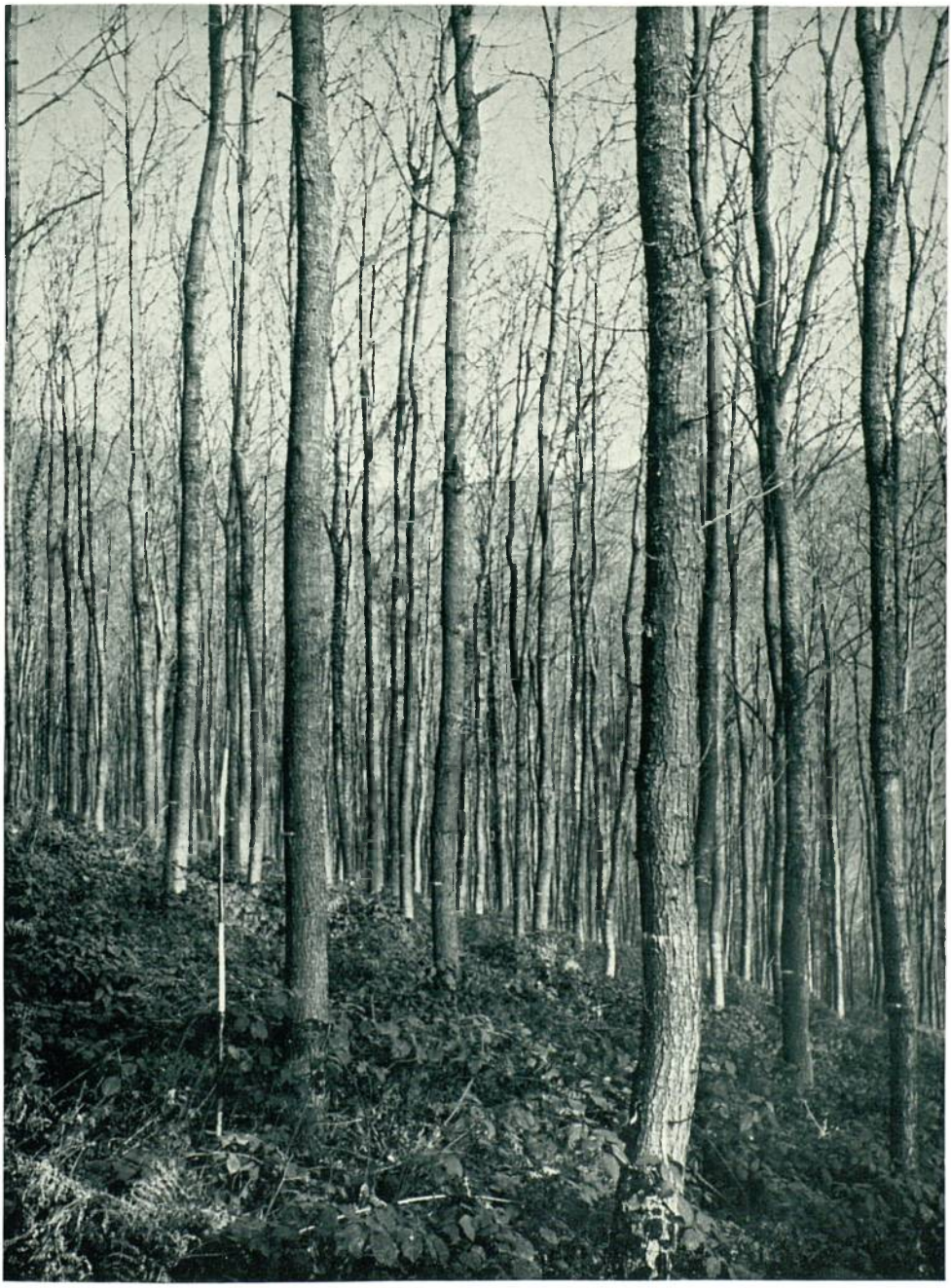

Plate 1. Sessile oak sample plot in Knockalls Enclosure, Forest of Dean. On Old Red Sandstone. Planted 1909. Data from 1950 measurement are : Age, 41 years ; top height 54 feet ; average breast-height quarter girth, 4½ inches ; volume, 2,150 hoppus feet per acre over bark ; stems per acre, 674 ; total production per acre, 2,750 hoppus feet. Thinned to Light Crown grade since 1928.

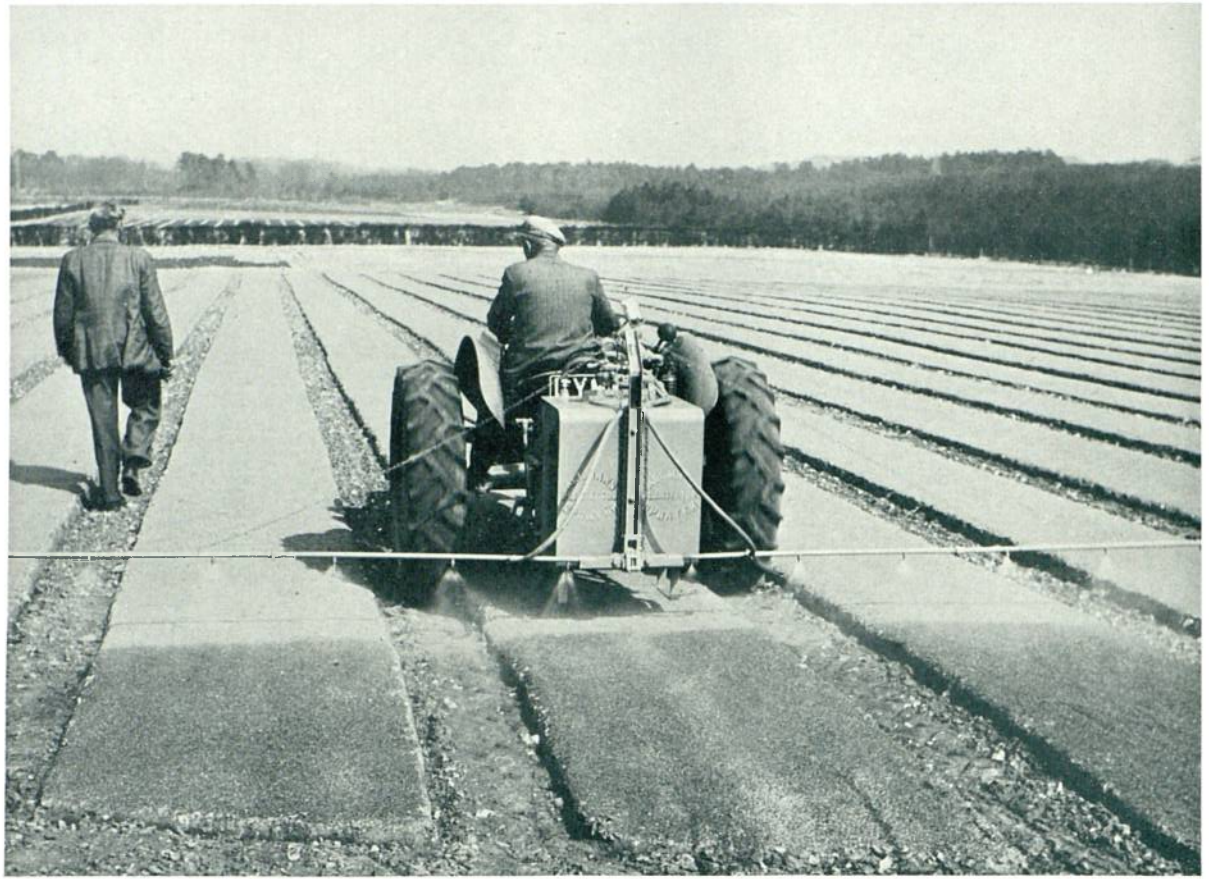

Plate 2. Tractor-mounted sprayer treating conifer seedbeds with a mineral oil spray, applied as a selective weedkiller before the tree seedlings emerge. Wareham Nursery, Dorset. (See page 28.)

Plate 3. Oscillating sprayline system for the overhead irrigation of seedbeds, at Kennington Nursery, Oxford. (See page 24.)

Plate 4. Trial plantation of the coastal race of *Pinus contorta* on deep *Scirpus* peat ploughed with deep single furrow Cuthbertson draining plough, at Strathy Forest, Sutherland. Planted 1949 ; each tree given 2oz. ground mineral phosphate. Height in 1953: 2 to 4½ feet. (See page 34.)

Plate 5. Over-mature hazel coppice growing on shallow soil over chalk in the South of England. Typical of many areas where returns from produce will not cover cost of clearing. (See page 77.)

Plate 6. Giant Rotavator cutting dense rhododendrons six feet tall, at Somerley Park, Ringwood Forest, Hampshire. (See pages 42 & 75.)

Plate 7. Typical windblow of Scots pine, caused by the great gale of 31st January 1953. The crop was seventy-four years old. Speymouth, Moray. (See page 47.)

Plate 8. Larvae of the sawfly *Diprion pini* feeding on Scots pine. Severe defoliation may result. (See page 71.)

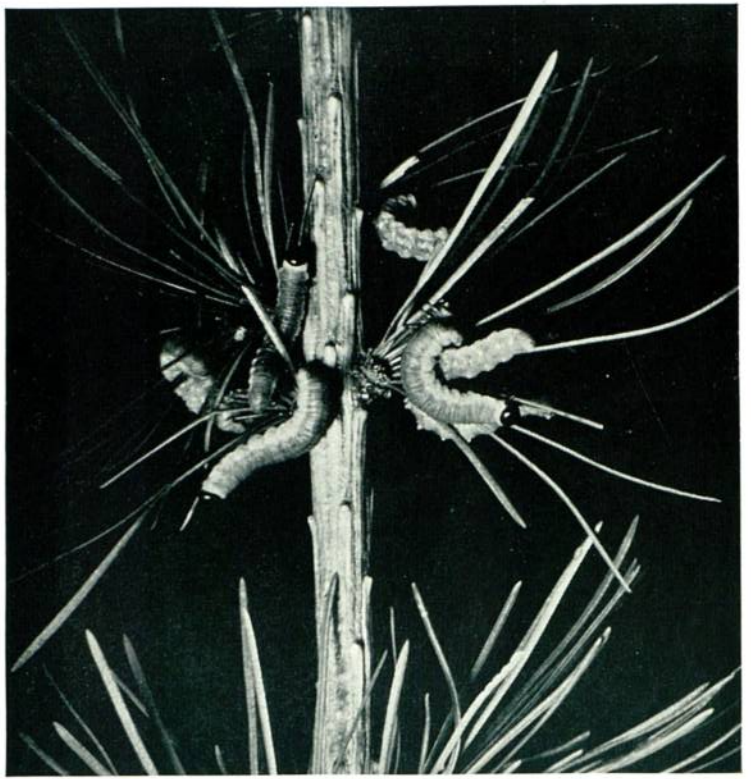

Plate 9. Larvae of the Large Larch Sawfly, *Pristiphora erichsonii*, feeding on European larch. (See page 70.)

Nectria spp., especially *N. coccinea*, are present on most affected stems, and this fungus is probably the most important accessory factor in the initial stages of the disease. Until more is known, it is difficult to give any recommendations concerning avoidance or control of the disease, but the indications are that they are more likely to be in the correct silvicultural treatment of beech, especially with regard to thinning, than in such measures as spraying.

A considerable number of such adaptations of silvicultural practice have been suggested, both in this country and abroad, for instance the avoidance of winter brashing of Japanes larch to avoid infection by *Phomopsis pseudotsugae*, which causes cankers; and the early brashing and opening up of *Thuja* plantations to lessen infection by the leaf and shoot fungus *Keithia thujina*. Recommendations on these lines however require considerable knowledge of the relationship of fungus and tree.

Adaptation of Nursery Practices

Investigation of nursery diseases tends to be easier than that of forest crops; and experiments on nursery stock, like experiments on agricultural crops, can often be completed in a single season. It is therefore rather easier to make recommendations for alterations in nursery practice designed to control or lessen attacks of disease.

For instance it was found some years ago that Leaf Cast of European larch, caused by the fungus *Meria laricis*, which could be controlled by spraying, was greatly lessened, if the plants were moved every year during their stay in the nursery. As a result, the aim became high fertility, allowing the production of one-plus-one planting stock. Curiously, the severity and incidence of this disease has vastly decreased as a result of the fall in popularity of European larch. It is not merely that far fewer plants are raised, but also that, as a result of this, carry-over of infection from year to year is much less, so that those plants which are grown tend to be much less attacked. Recent nursery surveys no longer reveal this as a serious disease, though it is still quite commonly found.

Botrytis cinerea attacking the succulent shoot tips of young conifers during the autumn and winter, came into prominence with the introduction of the heathland nursery, and the large, lush, long-season conifer seedlings produced therein. No satisfactory spraying regime can yet be recommended for this disease, and for the moment any measures such as reduction of manuring, which tend to reduce late growth, and protection against autumn frost, quite slight damage by which will often lead to severe *Botrytis* attack, are the only recommendations which can be made.

Keithia thujina on *Thuja* is another disease which has proved very difficult to control by spraying. Observation that the disease was completely absent from some nurseries, mostly those of fairly recent origin, led to the idea that such nurseries, if reasonably isolated from *Thuja* trees, could be used for raising the comparatively small number of *Thuja* required and could be kept free by introducing the species only in the form of seed. This is now standard practice in some Conservancies, and the movement of *Thuja* plants from one nursery to another is generally avoided. Trials of *Thuja*, sown in isolated nurseries to see how long they will remain free from infection, have been in operation for periods ranging from 2 to 5 years at 11 nurseries. During 1951 and 1952 *Keithia* was detected in three of these nurseries, and detailed investigation in 1952 disclosed that in two cases infected *Thuja* trees of some size were situated 0.3 miles (at Culmhead) and 0.6 miles (at Mabie) from the freshly infected nursery. At Montreathmont, however, no infected trees

were located within a one-mile radius. Obviously much care in the selection of isolated nurseries is required.

Treatment with Chemicals

Considerations of cost and accessibility nearly always limit spraying to nurseries, as far as forestry is concerned. With certain diseases, notably oak mildew and *Meria laricis*, spraying has proved reasonably successful, but with others such as *Keithia thujina* and *Botrytis cinerea* control has proved far from easy. With *Keithia* it seems probable that failure is mainly due to the extraordinarily long season during which the fungus continues to produce spores and the tree to remain susceptible. With *Botrytis*, failure is probably due to the rapidity with which fresh crops of sporophores are produced when one lot has been destroyed. This fungus has also proved very difficult to control in horticultural practice. One difficulty in spraying experiments has been the failure of infection to develop on the controls. Trials of various media in flasks have therefore been made to discover which can best be used to produce large quantities of *Botrytis* spores for artificial infection. Potatoes and bread were found to be the best substances.

A report has been prepared on experiments on the indirect prevention of elm disease, by spraying elms with D.D.T. to prevent feeding and consequent infection by contaminated elm bark beetles. In general the experiments supported American work in that this treatment, done correctly, could give fairly good protection, but at an exorbitant cost.

One difficulty about spraying in the forest nursery lies in the fact that to the forester in charge, the nursery may well be only one of many interests. When pressure of work is high, this often leads to neglect or postponement of spraying, either of which may be fatal to the whole spraying programme. Wherever possible, therefore, alternative methods of control should be suggested. This is one reason why, in the case of damping off of coniferous seedlings, dust treatment of seed, which can easily be made an integral part of sowing practice, is more attractive, as well as possibly more effective, than the application of dilute chemical solutions after the disease has been detected in action.

Experiments over the last two years on the treatment of seed of Scots pine and Sitka spruce with tetra-methyl-thiuram-disulphide, have shown that this substance can increase significantly the yield of seedlings. Pot experiments are now in progress to compare this substance with a number of other chemicals used in the past as seed treatments, in order to discover whether any other materials should be included, for comparison with TMTD, in future trials.

Wound Protection

Wound protection as a means of control or prevention only covers a rather narrow range of diseases. Protection of pruning wounds with substances such as tar, or white lead paint, has long been an accepted part of horticultural practice, but in forestry the protection of such wounds has usually been deemed unnecessary or too expensive. Expense is undoubtedly a serious factor, and, where pruning is restricted to small branches, protection should normally be unnecessary. But if decay-susceptible species, such as beech, are to be pruned, and if more attention is to be paid to the growing of hedgerow trees, which inevitably form large branches and require pruning, protection of wounds may well prove necessary. During recent years a large number of bituminous waterproof paints have come on the market, few of which have been tested as wound protectants. A preliminary experiment has been set up therefore

on pruned beech and lime (*Tilia*) at Buriton Forest, Hampshire, in which thirteen proprietary bituminous and similar preparations are being compared with unprotected wounds, and with wounds covered with white lead paint, shellac, grafting wax and paraffin wax.

No further work has been done on the protection of the stumps of pine thinnings against infection by *Fomes annosus*, which spreads subsequently to surrounding standing trees. The recommendations made by Dr. J. Rishbeth of the University Botany School at Cambridge, on the treatment of such stumps with tar-creosote mixtures were quite reasonable as regards cost, but have become less necessary in view of the unexplained reduction in severity of *Fomes* attack in the East Anglian pine forests.

Records of heavy *Fomes* infection in second rotation coniferous crops on ground previously under conifers, which are noted every year, do suggest that eventually experiments on the disinfection of stumps of a felled crop by chemicals may have to be undertaken; action of this nature might lessen the sources of infection to the subsequent crop.

Difficulties of Control

For a variety of reasons no control measures can yet be suggested for some of the diseases under investigation. In most cases this difficulty arises from incomplete understanding of the causation of the disease or of the relationship between the pathogen and the tree. For instance, studies on the leaf cast fungus (*Phaeocryptopus gaumannii*) of Douglas fir, carried out over the last five years, have not brought to light any connection with site, or variety, which could be used in the future as a means of avoidance. The investigation has shown, however, that in general the fungus has little effect on the growth rate of the tree, and can therefore be more or less left out of consideration, when the planting of Douglas fir is being considered.

At Bardney Forest in Lincolnshire and also at Harling near Thetford, dieback of thicket-stage oak has occurred, associated with the fungus *Diaporthe taleola*. The dieback is only locally serious, and may disappear as diseased trees become supressed; we do not yet know whether the *Diaporthe* is really solely responsible. Plots have been set up for the study of the disease, but until these have been examined over a period of years, it is impossible to make any worthwhile suggestions for treatment, except of course that diseased stems should be removed in the first thinning.

A resin flow of Douglas fir has been under investigation on three sites, one in Surrey, one in Kent and one in Gloucestershire, during the year. Patches of dead tissue, from which resin exudes, appear around the bases of branches or on the branches themselves. Their appearance is typical of fungal origin, but so far no pathogen has been detected. Again it is only possible to recommend that affected trees be removed in thinning.

Top dying of Norway spruce, a disease in which the tree withers from the crown downward, still defeats any satisfactory explanation. In a few instances it appears to be associated with drought and carries the warning that spruce should be used with caution on dry sites, but no recommendations can be made for its control.

The same is the case with the very dissimilar Group-dying of pole-crop conifers (mainly Sitka spruce). This is definitely a root disease, and affected trees have generally been found with small dead lesions all over the larger roots. But no pathogen has been isolated, and in view of the very wide range of sites and particularly of soils on which the disease occurs, any physiological explanation appears unlikely. Observational plots have shown that the normal

course of the disease is the rapid death of a group of trees over two or three years, followed by an almost complete cessation of spread in that particular group. This is comforting for the forester, but makes investigation into the effect of matters, such as thinning or draining, on the disease very difficult. Yet the disease is now sufficiently widespread to demand attention, and even small groups of dead trees in a pole-crop are serious as possible starting points for windblow. Investigations are therefore being continued.

It has been suggested that both these diseases, Top-dying of Norway spruce, and Group-dying of Sitka spruce, are due to inadequate available rooting depth, and that the sites on which they occur, would be better avoided for these species. In practice both diseases occur on a wide range of soils and sites, most of which are capable of producing financially successful pole-crops, and many of which are known to be capable of producing spruce of timber size. This being so, recommendations on site avoidance are hardly practicable, especially in view of the paucity of alternative species for many of the places where the disease occurs.

Conclusion

It will be seen from this discussion that many questions are still unanswered, and that the progress towards their elucidation, and towards the emergence of proper advice on control, is very slow. This is in some measure due to the amount of time spent on answering enquiries. It is hardly feasible to cut down an already insufficient, but desirable, advisory service, in order to leave more time for research. Yet until more research work is done the advice given will often be inadequate.

FOREST ENTOMOLOGY

By Dr. MYLES CROOKE
Forest Entomologist

Studies on Sawflies

Larch Sawflies

During 1952, observations on the status and distribution of the various species of larch sawflies were continued and the annual larch sawfly survey was expanded to include another fifteen forests in the south and east of Scotland.

The Large Larch Sawfly (*Pristiphora erichsoni* Htg.) was found in the new areas included in the 1952 survey, being particularly numerous in the southwest where on one forest (Auchenroddan), the largest nucleus of infestation so far recorded was discovered. This consisted of 593 larval clutches which were found on a sample area in vigorous Japanese larch crops of eighteen to twenty-one years of age. On areas visited in previous years, the 1952 assessment revealed only small fluctuations in population, with a general slight downward trend.

The other species of larch sawflies, usually referred to in general as the "small larch sawflies", were also found in the new areas surveyed, and these conformed to the general pattern of status and population density already known.

The two most widespread and numerous of the small larch sawflies were *Anoplonyx destructor* Bens. and *Pristiphora laricis* Htg. Populations of the

former were most dense at Drumtochty (Angus) and at Radnor forest on the Welsh borders, and at both of these places defoliation was marked. Elsewhere both *A. destructor* and *P. laricis* occured at fairly low population level and were not causing serious damage.

Pristiphora wesmaeli Tischb. was found to be less frequent than the preceding two species of small larch sawflies, mainly because its larval feeding habits restrict it almost entirely to very young crops.

Two further species—one as yet unidentified, and the other *Pachynematus imperfectus* Zadd.—were also found in small numbers in larch crops.

Spruce Sawflies

Studies on sawflies associated with spruce were also continued and the presence of seven distinct species in British forests was confirmed. Four of these are widespread and they occurred in small numbers on all the areas visited i.e. on the west from the Forest of Dean northwards through the Lake District to southwest Scotland. These four species are *Pristiphora abietina* Christ., *Pachynematus scutellatus* Htg., *Pristiphora ambigua* Fall., and *Pristiphora amphibola* Forst.

The remaining three species–*Pristiphora saxeseni* Htg., *Pachynematus montanus* Zadd., *Gilpinia hercyniae* Htg.—are less common. *G. hercyniae* was taken sporadically throughout the surveyed areas, whilst only a few specimens of *P. saxeseni* and *P. montanus* were found.

Laboratory Studies

During 1952 the laboratory studies on the taxonomy and biology of this group were intensified and expanded. When dealing with such a taxonomically complex group and with such a relatively large number of the species—(six on larch, seven on spruce, plus preliminary studies of three species—*Diprion pini L., D. similis* Htg., and *Neodiprion sertifer* Geoffr.—on pine) progress must necessarily be slow. Nevertheless, the skeleton of the life cycles of all species being handled is now clear, and detailed morphological descriptions of many of the stages have been prepared. Apart from this gradual accumulation of data on the morphology and biology of the species, the most concrete advance has been the clarification of the position of the species hitherto referred to in these reports as *Anoplonyx duplex* Lep. In co-operation with Mr. R. B. Benson of the British Museum this species was subjected to detailed study which revealed that it was not, in fact, *A. duplex*, nor any other hitherto described species. Although extremely common in Britain, the species is rare on the continent and is so far known to occur elsewhere in Europe only in Finland. The name *Anoplonyx destructor* Benson has now been designated to it.

East Anglian Insect Survey

This project was initiated in 1952 to make a general study of those forest insect species which appeared to be important in the large areas of pine in East Anglia. In addition to the review of the insect fauna of the district two distinct subjects were accorded more detailed investigation. The first of these was that of the status of *Bupalus piniarius* L. (the Pine Looper Moth, Bordered White or Pine Geometer); and the second a study of the forest relations of *Myelophilus piniperda* L. and other bark beetle species.

Pine Looper Moth, Bupalus piniarius

This insect is one of the most common and serious defoliators of pine crops in central and eastern Europe. It is a species which although indigenous

and common in Great Britain has not in the past caused any serious damage in this country. But as the extent of pole stage and older pine woodland in this country increases it may well be that *B. piniarius* will come to rank as a real forest pest. In Thetford, in particular, many conditions of forest extent and composition, and of soil and climate, approximate to those obtaining in continental localities where damage has been both frequent and severe, and it is obviously desirable that our knowledge of this species under these conditions should be expanded. The main objective towards which this study is directed are: (1) the confirmation of the biology of the species with particular reference to British conditions; (2) the assessment of the factors responsible for the natural control of this species, and the possible stability of these factors; (3) the development of techniques of population assessment and infestation forecasting.

Progress was made with the biological studies, data being gathered both in the field and from laboratory rearing. All stages in the life cycle have been described in detail, and various gaps in our knowledge of the life cycle have been filled. In the field of population assessment, greatest reliance is placed on a technique of cocoon counting in yard quadrats, on the lines already extensively used on the Continent. Numerous counts made in Thetford in January, 1953, revealed an average figure of 0.12 pupae per square yard in Scots pine crops. This approximated closely to the endemic figure of population (0.14 pupae/sq. m.) quoted by Schwerdtfeger (1930) for Letzlinger Heide in Germany; but when similar sampling was carried out at Culbin Forest, Moray, an average of 3.7 pupae per square yard was obtained. This is a disturbingly high figure and close watch will be kept at Culbin during the coming season.

The assessment of the nature and stability of natural control agents is complex, and it will take several years of detailed population studies before results become apparent.

A number of other lepidopterous pine feeders have been studied, and field keys have been drawn up for the differentiation of pine feeding lepidopterous larvae commonly found associated with *B. piniarius*.

Bark Beetles

Of these, *Myelophilus piniperda* is by far the most important, and a review of the situation revealed that the danger from this species is fully appreciated and that active countermeasures are taken against it. The high level of forest hygiene which is maintained is, of course, the best safeguard against population increase and consequent damage; but it is unfortunately true that as the thinning programme expands it becomes increasingly difficult to ensure that all material is expeditiously removed from the forest. When, for example, material is cut for a specific market which subsequently fails to assimilate it—a situation which did, in fact, arise locally in 1952—the danger of that material forming a breeding nucleus is clear. It would be advisable to have some form of emergency treatment other than peeling to deal with such a situation, and work in 1953 will include insecticidal treatments of such materials.

General

A list of all damaging forest insects and associated species was compiled from the survey data. This was built up mainly of well-known species, but a less known and interesting Eucosmid, *Enarmonia coniferana* Ratz. was found. The larvae of this species tunnel in the bark of *Pinus ponderosa* and their galleries were frequently found on stems which were exceptionally heavily buttressed. No evidence could, however, be gathered to prove that the activities of the larvae directly caused the butt swellings.

Insecticidal Control of Hylobius abietis

To see whether or not it was feasible to trap pine weevil successfully by substituting an insecticidal treatment of traps for the normal hand collections from traps, a series of trials was laid down on Witchill Estate, near Fraserburgh, Aberdeenshire. The five insecticides tested were benzene hexachloride, D.N.O.C., dieldrin, lindane, and a mixture of lindane and toxaphene. These insecticides were applied from a hand sprayer to billet and spray traps of normal construction at the rate of 200 cc. of a one per cent solution per trap, application being made in the first week of June and assessment and observations being continued until the end of August.

Data collected indicated:

(1) that there were in general no significant differences in the attractive or repellent qualities of the treated or untreated traps over the period of the experiment as a whole, but that immediately after treatment those traps treated with D.N.O.C. appeared to be more attractive to weevils than were the controls whilst traps treated with lindane/toxaphene were less attractive than controls.

(2) The efficiency of the insecticides, as assessed by computing and comparing the number of days to death of weevils removed from treated and control traps, was shown to fall in the order lindane/toxaphene, dieldrin, lindane, benzene hexachloride, D.N.O.C. Weevils from the traps treated with the first four insecticides lived for very significantly shorter times than weevils from untreated traps, whilst weevils from the D.N.O.C. traps lived for appreciably, but not significantly, shorter periods than weevils from controls.

Despite these apparently encouraging initial results it is considered that the technique of insecticidal trapping is one of doubtful practicability, and effort will next be directed towards ascertaining whether or not it is feasible to protect newly formed coniferous plantations from pine weevil by the application of insecticidal dusts to the plants themselves.

Use of Systemic Insecticides Against Adelges cooleyi

An experiment to test whether or not *Adelges cooleyi* on Douglas fir could be controlled by the application of systemic insecticides was laid down in Alice Holt forest in a crop eight years of age. Two insecticides, Pestox 3H and Hannane, were used; these were applied both by watering on to the soil and by direct spraying of the foliage. Neither of the compounds at any of the four application rates ("Pestox 3H" 1.0, 2.0, 4.0, 6.0 gms. per inch basal girth and "Hannane" 0.5, 1.0, 1.5, 2.0 gms. per inch basal girth), when applied by soil watering, resulted in any appreciable level of control. When applied by direct spraying, however, both substances at all four application rates ("Pestox 3H" 2.5 per cent active principle at four fluid ounces per tree and at two fluid ounces per tree, 1.25 per cent active principle at four fluid ounces per tree and at eight fluid ounces per tree: "Hannane" 0.25 per cent, 0.5 per cent, 1.0 per cent and 2.0 per cent active principle all at four fluid ounces per tree) yielded significant levels of control until approximately six weeks after spraying, when the populations on the treated trees began to rise.

Neomyzaphis Sample Plots

Six sample plots, three in the Forest of Dean and three in North-east England, were established in crops of about twenty years of age to study population fluctuations from year to year of *Neomyzaphis abietina* Walk., and the effect of varying degrees of infestation on the rate of growth of Sitka spruce. Assessments of both increment and aphis population are being carried out in May to coincide with the first seasonal peak in aphis population. The first assessment was carried out in 1952, and future ones will be continued for at least five years.

Gale Damage in Scotland

The devastation suffered by the forests of North-east Scotland from the gale which occurred on the 31st January, 1953, will undoubtedly lead to many serious and important insect problems, concerned particularly with bark beetle and weevil outbreaks. In the year under review, however, no work was actually carried out on those incipient problems beyond a general reconnaissance of the areas and an appraisal of the situation, to allow of plans being made to deal with future developments.

Advisory Work

One of the most interesting enquiries received related to the defoliation of a forty-acre crop of Sitka spruce aged twenty-five years on the Peckforton Estate in Cheshire. A visit to the area in July, 1952, revealed that many of the trees had lost most of their needles up to the current year's growth because of the activities of *Neomyzaphis abietina*. The general level of defoliation had been increased by the feeding of *Pristiphora abietina* on the current year's needles. On an excessively freely drained site it is probable that dieback and death will occur in 1953, and arrangements have been made to keep the area under observation. A particular point of interest is the occurrence of fully foliaged and apparently aphis-resistant trees throughout the crop. This aspect of the problem is being studied in co-operation with the Geneticist, and material from this crop will possibly be used in an attempt to propagate aphis-resistant strains.

MACHINERY RESEARCH

By R. G. SHAW
Machinery Research Officer

The following investigations have been undertaken during the past year:—

British Tractors

A wide range of British tractors is now on the market, and the first steps have been taken in the standardisation of the tractor fleet. Development of tractors for ploughing on very soft ground has continued, and the problem is now one of operating at an economic cost. As a result of successful experiments half-tracked tractors are now in use on a limited scale for the easier heathland ploughing in England and Wales.

Ploughing

An American mounted toolbar for fully tracked tractors was imported for trials, which have just commenced.

Work has continued on the special plough designed to throw both to left and right with a subsoiled path down the centre of the furrow. The object is to obtain the maximum width of cover to suppress weed competition, and a total width of 48 inches is achieved. This plough has been found to be very effective for the easier heathland sites, but in its present form it is not considered suitable for the harder rock-infested areas. On ground within its scope, costs are low as it is designed to operate as a mounted implement on a Fordson Major half-track tractor and can, in fact, operate on a wheeled Fordson if ground conditions are exceptionally good.

A wide range of drainage and tine ploughs continues to be used in the various conditions for which they are suitable.

Haulage Over Soft Ground

Attention has been directed to trailers for carrying light loads of forest produce, usually under three tons, over the frequently very soft and uneven feeder racks and rides.

In order to reduce surface damage on these feeder routes it is necessary to reduce the rolling resistance of the trailers, and experiments have been carried out to measure this resistance with different wheel equipments. It has been shown that by using large diameter (11 x 36) wheels instead of the more usual lorry wheel sizes, rolling resistance can be reduced by as much as 50 per cent. Tests with light rubber track units have shown them to be far less effective than the large wheels in soft mud. These trials are being continued on peat.

Fire Protection

A further development of the existing fire pump has raised the maximum head from 124 ft. to 155 ft. Weight and also price have been reduced. Experiments in Wales with one of these pumps mounted on a Land Rover and driven by the power take-off have been successful.

Cableways

A Swiss cableway has been imported for trials which will take place in Scotland during the summer of 1953. A lighter British-built cableway is in use in both Scotland and Wales. A method of using the operating winch to power load this cableway has been designed and will also be tested during the summer.

Clearance of Derelict Woodland

Trials with the Giant Rotovator and Grubber Blade have shown operating costs of £25 and more per acre, but this is considered to be near the economic limit for preliminary ground preparation.

Road Haulage

The Forestry Commission continues to use standard commercial vehicles as far as possible, and the general trend towards vehicles of greater payload has been followed. Increasing use of transporter vehicles is being made for the conveyance of tractors.

Nursery Cultivation

Further tests of lining-out machines have been made, but it has not been possible to achieve the close spacing of at most two inches that is required. Spraying machines to handle selective weedkillers are being developed to meet the particular conditions of forest nursery seedbeds.

The root pruning machines developed on the sledge principle in Scotland are now in wide use.

Mechanical hoes and cultivators are tested as they become available, if they appear to be applicable to forest nursery conditions.

Mechanical Loading

A Swedish lorry-mounted mechanical loader has now been widely adopted for loading timber in long lengths, both in Commission forests and by commercial operators.

Drainage

The cleaning of drains in young plantations is a current problem owing to the impossibility of using a tractor in the confined space available. A machine designed to pull itself by its winch along these drains is being developed.

UTILISATION DEVELOPMENT

By E. G. RICHARDS
Utilisation Development Officer

In accordance with the recommendation of the Advisory Committee on the Utilisation of Home Grown Timber, work was carried out during the year, under four main heads, on problems affecting the utilisation of:—

(i) Small conifer thinnings.
(ii) Small hardwood thinnings.
(iii) Scrub and coppice.
(iv) Sawmill and other waste.

Small Conifer Thinnings

Between 1950 and 1952 a demand arose for small-sized coniferous thinnings for use in the manufacture of a special type of paper formerly made from rags. Investigations showed, however, that the use of timber in preference to rags was occasioned by a steep rise in the price of rags rather than for any technical reasons. The manufacturers concerned were in a position to revert to the use of rags at any time they so desired; i.e. as and when the price of rags fell to an economic level. The price of rags appears to be still liable to considerable fluctuation and it is therefore too early to conclude that a new and permanent outlet for small-sized coniferous thinnings exists.

Small Hardwood Thinnings

An investigation into the wood-turning industry in Scotland was carried out during the early part of 1953 with a view to finding out the extent to which this trade makes use of home-grown hardwood, particularly from thinnings, and in the case of birch, from scrub.

Some 76 firms believed to be connected with wood turning were approached during the investigation. The names of 59 of these firms were recorded in the files of the National Home Grown Timber Council (1935). It was found that today 27 firms were operating full-time turneries, 23 were operating part-time turneries, 17 firms were no longer in existence, 4 had completely abandoned turning and 5 of the firms approached were in fact only remotely connected with wood turning. Many firms operating full-time turneries had another line of business, ranging from that of the large timber merchant to that of the smaller firewood merchant ; but all attached considerable importance to the operation of their turnery departments. In the case of the 23 firms operating part-time turneries, however, wood-turning was engaged in either to complete a comparatively small, though essential, part of a wood shaping process, or to meet *ad hoc* demands for turned articles.

The largest item of individual importance to the Scottish wood-turning trade is the bobbin, the term here being used to cover what are also variously and sometimes more accurately described as reels, spools and pirns. Equally essential to the textile trade is, of course, the shuttle, which is manufactured for the most part by specialist firms; one which still uses water power was established as long ago as 1844. Other specialist manufactures include spiles and shives, clothes pegs, the pipes of the bagpipe, and chanters. In the wider field of general turnery the manufacture of turned furniture parts probably

accounts for the greatest consumption of timber, though a wide range of articles of both a decorative and purely utilitarian nature is produced. In general, although it is estimated that the industry still consumes about half a million hoppus feet of home-grown hardwoods annually, the total demand for turned goods has fallen steadily over the last half century. Modern "square" styles of furniture and ornamental woodwork have ousted many of the traditional styles which embodied shapes most easily achieved by turning. This change in fashion was noted in a previous survey in 1935. The Windsor chair which was then recorded as being replaced by cheaper imported bentwood chairs, is once more enjoying a considerable measure of popularity together with certain types of "antique" turned legs and feet for furniture. These apart, however, there has been no reversal of the general trend towards the more severe styles.

In other spheres, too, turnery has suffered from a lessening demand. Thus the wooden bobbin has now to compete with the plastic and paper bobbin, whilst the Indian market which formerly took a big share of Scottish output has been virtually lost to the Indian-made bobbin. Again, before the Second World War the "power tools" of agriculture were mainly operated by the horse and embodied in their design a considerable amount of turned woodwork. With the advent of tractor farming, wood has almost disappeared from the modern agricultural implement in much the same way as it has done from the modern motor car. From these examples it will be seen that the problem of stimulating the demand for home-grown timbers by the wood-turning trade is one that is bound up closely with the future of an industry still very active but fighting for its existence in face of the diminishing industrial and domestic consumption of turned wood.*

Scrub and Coppice

The Rural Industries Bureau completed their survey of the underwood industry, to which reference was made in last year's report. The results have been summarised for the hazel underwood industry and are now being worked out for other species. In the case of hazel it appears that only about 12,000 acres of hazel coppice are required to maintain the industry at its present size, allowing for rotations up to ten years. Although the hazel underwood industry is the main user of hazel coppice worked on a regular rotation, a certain amount is cut to meet local demands by private estates and others outside the industry. It is not considered likely that cutting outside the main industry to meet *ad hoc* demands will utilise a larger area of hazel than that worked by the underwood industry. But even if one makes an allowance of a further 12,000 acres to meet this requirement, there are still nearly 150,000 acres of hazel coppice and scrub in the country for which no demand appears to exist. There are no indications that a larger area will be worked in the future unless new uses for hazel are found. Whilst it is true that the demand for wattle hurdles—or more strictly that for garden screens—is increasing, the demand for the other major product of the industry, pottery crate rods, is declining. Moreover, the industry may not be able to take advantage of the increasing demand for garden screens, because there is already a shortage of skilled hurdle-makers and comparatively few young men have so far shown willingness to learn this craft.

An attempt was made to test the suitability of hazel for making fibreboard, and some fifty tons of hazel were made into fibreboard in a full-scale mill trial using a mechanical pulping process. The material consisted of unbarked

* The full report is published as Forest Record 27. *Use of Home-grown Timber in Wood Turning and Related Trades in Scotland in 1953.* H.M.S.O., 1s. 3d.

hazel shoots over two inches in diameter, since the existing plant was unable to handle smaller dimensions of timber. Whilst the results were satisfactory, it was pointed out by the firm concerned that hazel is not likely to be used commercially for fibreboard production as long as there are adequate supplies, for this purpose, of conifers, willow and poplar.

Paper making trials were conducted by the British Paper and Board Industry Research Association on a laboratory scale. In these trials the hazel was not limited to material over two inches in diameter, but consisted of whole shoots. A chemical method of pulping which could be used in a British paper mill was employed, viz. the caustic soda process. Preliminary reports indicate:—

(*a*) Hazel wood shoots can be pulped satisfactorily with caustic soda solutions without removal of bark.

(*b*) Bleached pulp with a reasonably good degree of whiteness can be produced by treatment with calcium hypochlorite solution.

(*c*) The bast fibres from the bark are fairly short, and do not contribute any outstandingly valuable characteristics to the pulp.

(*d*) Laboratory sheets prepared from hazel pulp have good strength properties, good formation and good capacity. On the mill scale such a pulp could be converted into a useful printing paper. Long-fibred softwood pulp may be a necessary addition to reduce breaks on the paper machine.

With regard to (*c*) the Research Association report as follows:—

"*Fibre Dimensions.* Work carried out in Canada on the pulping of orchard slash (Crossley, T.L., *Pulp and Paper Mag., Canada, 53*, No. 7, 126) and other waste woods of less than three inches in diameter had shown that valuable long bast fibres were often obtained from the bark, the amount increasing as the diameter of the wood decreased. The presence of these long bast fibres, together with the short deciduous wood tracheid fibres, gave a pulp which could be run satisfactorily on the paper machine without the addition of long-fibred softwood pulp. It was obviously of interest to determine whether long bast fibres were contributed by the hazel wood bark.

"A representative sample of hazel wood shoots was boiled in water and the bark stripped away by hand. The weight of bark was found to be 15 per cent of the total wood weight. The bark and stripped wood were then reduced to fibrous pulps separately and the pulps examined under the microscope. The bark pulp fibres were quite short, varying in length from 1.0 mm. up to 1.6 mm., and the fibre walls were thicker than those of the wood tracheids. The wood tracheid fibres varied in length from 0.3 mm. up to 0.9 mm., and had fibre diameters varying from 0.008 mm. up to 0.024 mm. It will be observed, therefore, that whilst it has been established that hazel wood shoots can be pulped satisfactorily without prior removal of bark, very little additional value is gained by the inclusion of the bark from the point of view of supply of long bast fibres".

Chestnut Coppice

During the winter of 1952/53 the Mensuration Section of the Research Branch carried out a series of measurements in Chestnut coppice of different qualities in Kent. After determining the age, height, number of stools and shoots per acre, chestnut in one tenth-acre plots was felled, and trimmed out. The trimmed shoots were then cross cut at the 2½ inch diameter point.

The tops, i.e. material *under* 2½ inches diameter, and the trimmings, were then worked over by a craftsman, in co-operation with the Mensuration Section Party. The amount of produce obtained was recorded by assortments, e.g. fence stakes, hedge stakes, flower stakes, bean rods, pea boughs.

The material *over* 2½ inches in diameter was cleft into cleft fencing pales by a craftsman; the number of pales so prepared was recorded, by sizes.

During these operations records of weights, moisture contents and densities were kept.

It will be possible to show from the data obtained the yield of chestnut coppice in terms of weight, volume and produce obtainable. Since chestnut coppice workers are paid on piece-work rates it will be possible to draw up an approximate balance sheet showing the average cost of felling and preparing chestnut coppice against the value of the prepared produce.

Waste

An investigation into the manufacture of wood flour in Great Britain revealed that in 1951 the industry absorbed some 38,000 tons of sawdust, shavings and, to a much lesser extent, mill off-cuts. The bulk of this waste was obtained from the conversion or manufacture of imported conifers, chiefly Norway spruce, Scots pine and Douglas fir. For a variety of reasons, but principally because of its relatively high moisture content, sawdust from home grown timber is not used to any extent in wood flour manufacture. Were it possible to obtain, over a long period, supplies free from bark, with a moisture content below 25 per cent, there would be no real objection to the use of waste from home-grown timber. In this connection it is perhaps worth noting that wood flour must be free of colour for many purposes, and the quantity manufactured from "coloured" sawdust is of necessity limited. Anyone contemplating the sale of home-grown sawdust in this market should therefore bear in mind the advisability of keeping spruce sawdust separate from that of species with a coloured heartwood like Scots pine and Douglas fir.*

A visit was paid to Germany to study the production of building boards from waste timber on what was reputed to be a smaller scale than that considered economic in Great Britain.

The smallest fibre building board unit seen had a weekly intake of about 210 tons of sawmill slabs and roundwood off-cuts, all produced within a short radius of the factory. It was stated that this advantage, i.e. the low cost of the raw material, offset the comparatively high overheads and daily running costs, associated by the Germans with board mills with a weekly intake of under about 700 tons of timber. However, the initial cost of such a plant was given as being in the region of £250,000, and the production of 210 tons of genuine waste timber per week involves the handling of several million cubic feet of timber annually.

The other factory of most interest was concerned with the production of wood wool and gypsum building boards. Although the greater part of the production is carried out by mechanical means using a continuous process, high quality special purpose boards are also made in hand presses in the same factory. It was stressed by the management, however, that the economic running of the mechanical side of the business depended on the availability of a cheap raw material almost as much as did the much smaller hand-operated side. The firm had in fact undertaken the manufacture of pit props and sawn lumber at a site adjacent to the factory in order to secure adequate supplies of cheap roundwood waste.

* The full report is published as Forest Record 21. *Use and Manufacture of Wood Flour.* H.M.S.O., 6d.

THE LIBRARY AND DOCUMENTATION CENTRE AT ALICE HOLT

By G. D. KITCHINGMAN
Documentation Officer

Books Section. The number of books in the library increased from 1,785 to 2,075—an increase of 975 in the last four years. 468 books are on permanent loan to sectional libraries. Loans from the Lending section to borrowers outside the building were 354. Grateful acknowledgement is made to the Imperial Forestry Institute, the Science Museum and other libraries for the loan of books which, during the year, amounted to 294 items.

Periodicals Section. 70 volumes of periodicals were bound, bringing the total to 990.

Information Files. Considerable progress was made in this section, but no measure of the increase has been attempted.

Documentation. The number of cards in the indices is now about 47,000, equivalent to about 15,000 references. Documentation work is seriously in arrears, but now that a post of library clerk has been sanctioned there should be more time to give to this work. This is important because requests for lists of references are increasing.

Photograph Collection. The Commission's collection of photographs was transferred to the library during the year. On March 31st there were 5,359 black and white prints and 850 colour slides.

Library Quarterly. Four numbers of the Quarterly were issued during the year. The four Library Records issued with them dealt with:

(1.) A New British Flora.*
(2.) Partial Sterilisation of soil by steam.
(3.) Red Oak in Belgium, Denmark and France.
(4.) Translations in the Documentation Centre.

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

Gifts. Acknowledgements for presentation of books to the library are due to Lady Robinson and to the Librarian, Imperial Forestry Institute, Oxford.

PHOTOGRAPHY

By I. A. ANDERSON
Senior Photographer

Three conservancies, North-east England; South Wales; and East Scotland were visited during the year to take photographs required for record and research purposes.

* *Flora of the British Isles.* Clapham, Tutin and Warburg. Cambridge University Press, 1952.

In North-east England seven forests were visited and some 400 photographs were taken. In South Wales eighteen areas were visited and some 700 photographs were taken. In East Scotland twenty areas were visited and some 375 photographs were taken.

In addition over 400 photographs were taken and over 5,000 prints made for Research Branch and the Conservancies.

During the year under review the amount of black-and-white work has increased slightly, but not so much as the demand for colour slides. Apart from re-editing the "Culbin Story" to produce a twenty-minute version, no work on cine films has been undertaken.

PUBLICATIONS

The following papers by members of the Research Branch staff were published during the year.

BROWN, J. M. B. — *Studies on British Beechwoods.* Forestry Commission Bulletin No. 20 (January 1953), H.M.S.O. 12s. 6d.

" " — Report on Technical Meeting in London of Royal Forestry Society of England and Wales, 14th May, 1952. *Quarterly Journal of Forestry.* Vol. XLVI. No. 4. pp. 225-227 (Oct. 1952)

CHARD, J. S. R. and others — *Census of Woodlands 1947-1949. Woodlands of Five Acres and Over.* Forestry Commission Census Report No. 1 (April 1952), H.M.S.O. 12s. 6d.

CHRISTIE, J. M. — "Smallwood" from Conifer Thinnings. *Quarterly Journal of Forestry.* Vol. XLVI. No. 4. pp. 243-246 (October 1952)

CROOKE, MYLES — *Adelges attacking Japanese and hybrid larches.* Forest Record No. 17, H.M.S.O. 1s. 3d.

EDWARDS, M. V. — *The effects of partial soil sterilization with formalin on the raising of Sitka spruce and other conifer seedlings.* Forest Record No. 16 (1952), H.M.S.O. 1s. 6d.

FAULKNER, R. — Early observations on the Root Development of one-year-old Corsican pine seedlings following root pruning. *Scottish Forestry.* Vol. 7. No. 1. pp. 23-26 (1953)

" " — Notes on Nursery Irrigation and on Chemical Weed Control Practices in the U.S.A. and Canada. *Forestry.* Vol. XXV. No. 2. pp. 126-134 (1952)

" " — American Nurseries and Nursery Practice. *Arbor,* Aberdeen University Forestry Society Journal, Vol. 2. No. 1. pp. 22-25 (1952)

HANSON, H. S. — Megastigmus Seedflies. *Quarterly Journal of Forestry.* Vol. XLVI. No. 4. p. 261 (1952)

JEFFERS, J. N. R. *The Use of Statistical Methods in Forest Research.* Paper presented to the Sixth British Commonwealth Forestry Conference, Canada 1952. Forestry Commission, London.*

" " *Experimental Designs and Analyses used by the Research Branch of the British Forestry Commission.* International Union of Forest Research Organisation. Fifth Communication of Section 23. (April 1952)

KITCHINGMAN, G. D. An outline of French Silvicultural Literature. *Forestry.* Vol. 25. No. 2. pp. 135-142 (1952)

MATTHEWS, J. D. The introduction of some exotic tree species. *Sylva.* Edinburgh University Forestry Society Journal. No. 33. pp. 11-13 & 29. (1952-3)

" " Forest Tree Breeding in Britain. *Zeitschrift für Forstgenetik und Forstpflanzenzuchtung.* 2. p.p. 59-65. March 1953.

MACDONALD, JAMES *The Place of North-Western American Conifers in British Forestry.* Paper presented to the Sixth British Commonwealth Forestry Conference, Canada 1952. Forestry Commission, London.*

" " Recent developments in forest nursery practice in Great Britain. Paper presented to the British Association Meeting, Belfast, 1952. *British Agricultural Bulletin.* V. 23. p. 324. January 1953. Reprinted in *Quarterly Journal of Forestry*, XLVII, No. 2. p.p. 89. April 1953

MACDONALD, JAMES AND HENDERSON, F. Y. La investigacion en el Reino Unido. *Montes.* No. 50. March-April 1953

MACDONALD, J. A. B. AND MACDONALD, A. The effect of interplanting with pine on the emergence of Sitka spruce from check on heather land. *Scottish Forestry.* Vol. 6. No. 3. pp. 77-79 (July 1953)

MOORE, P. Scots pine on a disused and burning coal tip. *Quarterly Journal of Forestry.* Vol. XLVI. No. 4. pp. 250-255 (Oct. 1952)

MURRAY, J. S. Recent Research on Forest Pathology in Holland. *Quarterly Journal of Forestry.* Vol. XLVII. No. 1. pp. 41-47. (Jan. 1953)

PEACE, T. R. The Pathological Section of the Forest Research Station. *Journal of the Royal Institute of Chartered Surveyors.* Vol. XXXII. No. 2. pp. 114-116, (1952)

" " The effect of Atmospheric Pollution on Forest Trees in Great Britain. *Smokeless Air.* Vol. 83. pp. 12-16, (1952)

" " *Poplars.* Forestry Commission Bulletin No. 19, H.M.S.O. 7s. 6d.

" " The defoliation of Pines with particular reference to *Lophodermium pinastri.* *Scottish Forestry.* Vol. 7. No. 1. pp. 17-22 (1952)

* See footnote, page 83.

RICHARDS, E. G. AND PEARSON, F. G. O. — *Utilisation of Young Plantation Timbers in Great Britain.* Paper presented to the Sixth British Commonwealth Forestry Conference, Canada 1952. Forestry Commission, London.*

SHAW, R. G. — *The Use of Large Diameter Wheels and Tyres on Forest Extraction Vehicles.* Forest Record No. 18, H.M.S.O. 9d.

WEATHERELL, J. — The checking of forest trees by heather. *Forestry.* Vol. XXVI. No. 1. pp. 37-40 (1953)

ZEHETMAYR, J. W. L. — Problems of Moorland Afforestation. *Quarterly Journal of Forestry.* Vol. XLVII. No. 1. pp. 32-40 (Jan. 1953) *Reprinted in British Agricultural Bulletin.* Vol. 5. No. 23. pp. 329-332. (Jan. 1953)

* Copies available on request from the Secretary, Forestry Commission, 25 Savile Row, London, W.1.

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

NUTRITION PROBLEMS IN FOREST NURSERIES, SUMMARY REPORT FOR 1952*

By

Dr. E. M. CROWTHER, R. G. WARREN and BLANCHE BENZIAN

Rothamsted Experimental Station, Harpenden, Herts.

Introduction

The general programme and the methods of conducting nursery and forest experiments were described in some detail in the Summary Report on 1951 Experiments and are not repeated here. We hope to continue most of our nursery experiments for several years and to have as many as possible in parallel at several of the six nurseries in which we are working. Each year since 1947 we have laid out forest planting experiments in at least two forests. In these ways we hope to obtain a reliable and representative basis for our findings. We have had several instances in which it might have been misleading to have drawn general conclusions from a single precise but isolated experiment.

A large proportion of our experiments have been devoted to studying the role of organic matter from green crops or composts in maintaining soil fertility, a subject which has long remained controversial, largely because reliable experimental data are difficult to obtain. A large part of the present Summary Report deals with results of experiments carried out on many plots for four or five years at three nurseries, and to the first-year results of two experiments planned to run for many years. So far these experiments have shown little benefit from using organic manures in place of inorganic fertilizers, or from interrupting continuous Sitka spruce seedbeds to introduce rotation crops. Many experiments are made in forests to test the performance of seedlings and transplants raised with contrasted methods of manuring.

In the present report special attention is given to seedbed experiments completed in 1952. To save space and to simplify tables, details on the design of experiments, the sizes of plots, the rates of dressings, the standard errors and the levels of significance are omitted from this Summary Report. Full details of the nursery and forest experiments are given, for reference, in the Annual Reports presented to the Sub-Committee on Nutrition Problems in Forest Nurseries. A considerable number of chemical analyses of soils and plants have been carried out each season and a number of preliminary tests made in pot cultures at Rothamsted. The results of these investigations have been used in planning the nursery and forest investigations, but the results have not yet been published.

* Report presented to the Sub-Committee on Nutrition Problems in Forest Nurseries.

The 1952 season

A number of results in nursery experiments were different in 1952 from other recent years. Thus, in several experiments in their third or fourth seasons with successive annual crops of one-year Sitka spruce seedlings, there was poor growth throughout a whole experiment or for a group of treatments. In several experiments plots treated with compost gave particularly poor stands of plants. In one nursery—Ampthill—almost the whole of the experimental crop failed. There was a pronounced drought in the early summer of 1952; this was particularly serious since sowing was much later in 1952 than in the three preceding years. It is possible that in some experiments there may, also, have been a progressive increase in soil-borne pests and diseases, especially on compost plots, but no certain diagnosis has been made. We must look to the continued results of current experiments to see whether the abnormalities of 1952 were essentially accidental or whether they represented the first stages of break-down in our attempts to grow usable one-year Sitka spruce seedlings year after year on large numbers of small experimental plots. The 1953 crop was sown much earlier, though in this season the advantage from early sowing may be less than it might have been in 1952, because germination was very slow in the particularly cold and dry spring of 1953. This circumstance provides another illustration of the need for repeating many experiments over several seasons to obtain representative data.

A Five-year Experiment on Organic Manures and Fertilizers at Bagley Wood, Oxford, 1948 to 1952 (B 12)

The field experiments conducted for the Sub-Committee in 1945 and 1946 had been devoted mainly to testing a number of organic manures and fertilizers, alone and in combination, and to developing a suitable plot technique. These experiments suggested that the effects of composts, then believed to be essential for maintaining productivity, could be ascribed in large measure to the major nutrient elements present in the composts. It was decided in 1947 to prepare special lots of compost and raw materials for an experiment to be started in 1948 on poor, very acid soil in Bagley Wood, Oxford. This experiment was continued for five seasons and had to be discontinued after 1952 because the original beds had been lowered almost to the level of the alleys by removing stones in the annual preparation of seedbeds. Crops were poor in the first two seasons but, after a light liming on all plots in January 1950, good crops were grown in the next three seasons.

Six composts and three uncomposted materials were tested. Hopwaste was composted alone and with either chaffed green bracken or wheat straw. The other three composts were prepared with fertilizers: straw with inorganic fertilizer, straw with organic fertilizer, and chaffed green bracken with superphosphate. The three uncomposted materials were fresh hop waste, dried chaffed green bracken used with superphosphate, chaffed wheat straw used with superphosphate and nitrogen top-dressings. Each of these nine treatments was tested alone and with additional "single-rate" applications of superphosphate and potassium chloride to the beds and nitrogen top dressings. There were also, in each block, a pair of unmanured plots, a pair with "single-rate" fertilizers and a pair with "double-rate" fertilizers. The experiment had 96 plots in four blocks.

The nine organic manures varied widely in their chemical and physical properties. The bracken products were hard and stemmy. The hopwaste, as usual, contained very little potassium. The composts from straw and fertilizers contained more inorganic nitrogen than the other materials. Some of the composts supplied from three to five times as much nitrogen or two to

three times as much phosphorus or potassium as was given in the "single-rate" fertilizers. In 1951, and to a less extent in other years, seedlings on the fertilizer plots and some of the compost plots developed a characteristic discoloration, which has been proved in other experiments to be a symptom of magnesium deficiency. No magnesium fertilizer was added in this experiment, in order to maintain continuity with the earlier years.

Average analyses of the organic manures are given in Table 18 and the mean heights over five seasons and the mean annual changes in heights in Table 19, which also gives the amounts of nitrogen, phosphorus and potassium supplied at the rates of dressing chosen.

AVERAGE COMPOSITION OF ORGANIC MANURES
BAGLEY WOOD EXPERIMENT (B 12), 1948-52

Table 18

	Percentage of material as applied						
	Dry matter	Organic matter	Inorganic N	Total N	P	K	Mg*
Composts prepared from							
Hopwaste	21.7	15.2	0.05	0.94	0.27	0.06	0.080
Bracken+hopwaste	27.8	19.5	0.08	0.92	0.18	0.47	0.074
Straw+hopwaste	19.6	14.7	0.05	0.81	0.19	0.14	0.078
Straw+inorg. NP fertilizer	28.3	19.0	0.36	0.85	0.35	0.30	0.060
Straw+org. NP fertilizer	26.5	19.6	0.18	1.01	0.43	0.36	0.052
Bracken+superphosphate	27.4	21.2	0.08	0.61	0.32	0.47	0.052
Uncomposted materials							
Hopwaste	13.1	12.0	n.d.	0.67	0.12	0.02	0.058
Dried green bracken	81.4	75.5	n.d.	1.73	0.15	1.69	0.106
Straw	82.9	77.4	n.d.	0.50	0.08	0.70	0.059

* Average of two seasons only
n.d.=no data.

The mean heights of one-year Sitka spruce seedlings ranged from 1.2 inches on unmanured plots to 2.6 inches for the best treatment. The "double-rate" fertilizers gave slightly higher mean heights than any of the organic manure treatments used without additional "single-rate" fertilizer. The mean annual change in the heights of seedlings was 0.32 inches for fertilizers at "double-rate", as compared with 0.18, 0.28 and 0.33 inches for hopwaste composted alone, with bracken and with straw, respectively. There was, therefore, no indication over five years that fertilizers alone were inferior to composts in maintaining productivity, apart from the risk of magnesium deficiency, where this was not included in the fertilizer.

In the drought year of 1949, before limestone was applied, there was no benefit from fertilizers and only a small one from composts. In later years fertilizers gave larger plants than composts prepared without fertilizers, in seasons of good rainfall and growth.

As in many other experiments, composts gave fewer plants than fertilizers. The mean numbers per square yard over five seasons were:

	No fertilizer	*Single-rate fertilizer*	*Double-rate fertilizer*
No organic manure	1310	1240	1280
Composts	1170	1140	—
Raw organics	1090	1020	—

Since the raw hopwaste, used fresh or composted alone, was notably deficient in potassium, the results for organic manures in Table 19 are given in two separate groups for high-potassium and low-potassium dressings. Within each group the treatments are arranged in order of decreasing supply of phosphorus. It will be seen that, where adequate amounts of potassium were supplied (Group A), the mean heights and mean annual changes in height followed substantially the same order as the amounts of phosphorus, whether or not organic manures were used, and independently of the kind of organic manure. The results show that, to a first approximation, the behaviour of a widely contrasted group of manures and fertilizers depended essentially on the amounts of phosphorus and potassium furnished, and that little remained to be ascribed to other chemical, physical or biological factors.

BAGLEY WOOD EXPERIMENT ON ORGANIC MANURES AND FERTILIZERS, 1948-52
MEAN RESULTS FOR ONE YEAR SITKA SPRUCE (B 12)

Table 19

	Mean height in inches		Mean annual change of height in inches		Nutrients supplied in "Treatment alone" grams per sq. yd.		
	Alone	+ Single NPK	Alone	+ Single NPK	N	P	K
A. *Organic manures supplying more than 2 grams K per sq. yd.*							
1. *Composts prepared from*							
Straw+org. NP fertilizer	2.15	2.38	0.39	0.33	23	9.7	8.1
Straw+inorg. NP fert'r.	2.07	2.55	0.42	0.44	19	7.8	6.8
Bracken+superphosphate	1.90	2.31	0.28	0.40	14	7.3	10.6
Straw+hopwaste	1.88	2.30	0.33	0.29	18	4.2	3.2
Bracken+hopwaste	1.70	2.11	0.28	0.29	21	4.2	10.8
2. *Uncomposted materials*							
Bracken+superphosphate	1.68	1.96	0.22	0.28	12	4.2	11.5
Straw+NP fertilizer	1.72	1.90	0.30	0.22	9	3.7	4.8
B. *Organic manures supplying less than 2 grams K per sq. yd.*							
Compost from hopwaste	1.65	2.36	0.18	0.37	21	6.1	1.4
Fresh hopwaste	1.39	2.12	0.17	0.21	30	5.4	0.9
C. *No organic manure*							
Double NPK fertilizer	2.18	—	0.32	—	12	6.5	6.9
Single NPK fertilizer	1.86	—	0.28	—	6	3.2	3.5
D. *Unmanured.*	1.16	—	0.06	—	—	—	—

Rates of application per sq. yd.:

Composts	5 lbs.
Fresh hopwaste	10 lbs.
Dried green bracken	1.5 lbs. (+3.2g.P)
Straw	1.5 lbs. (+6.0g.N, 3.2g.P)
"Single-rate" fertilizer	6.0g.N, 3.2g.P, 3.5g.K

Fertilizers applied: N—Nitrogen as ammonium sulphate or "Nitro-Chalk"
P—Phosphorus as superphosphate
K—Potassium as chloride

There was no evidence, over five years at least, that supplying organic matter or composting it contributed appreciably to improving or maintaining productivity. This experiment was unsuitable for a longer test, and two other

experiments have been started at Wareham, Dorset and Kennington, Oxford with precautions intended to allow them to be continued for many years.

Preliminary Rotation Experiments at Kennington Extension and Wareham 1948-52

Two series of rotation experiments were started at Kennington Extension and Wareham on new sites each year from 1948 to 1950. In the first year of each experiment there were six cropping treatments: yellow lupins, rye, perennial ryegrass, S.100 white clover, one-year Sitka spruce seedlings and bare fallow. In the second and third years one-year Sitka spruce was grown as a test crop, half of the plots having compost of bracken and hopwaste and the other half inorganic fertilizer. Each series had four blocks of 12 plots in each phase, or 144 in all. The first experiments, with treatment crops in 1948, had them again in 1951 and carried "first-year" Sitka spruce crops in 1949 and again in 1952. The other two experiments, started in 1949 and 1950 respectively, went through only one cropping cycle.

SITKA SPRUCE SEEDLINGS GROWN AS FIRST AND SECOND CROPS AFTER GREEN CROPS OR FALLOW

Table 20 Means of three crops, 1950-52

	Kennington Extension (KE 34, 46, 47)		Wareham (W 28, 48, 58)	
	First crops	Second crops	First crops	Second crops
	Height in inches			
After				
Lupins	1.9	2.0	2.4	2.8
Clover	1.9	2.0	2.6	2.2
Rye	1.9	2.0	2.5	2.4
Ryegrass	2.1	2.0	2.4	2.3
Bare fallow	2.1	2.0	2.9	2.1
Sitka spruce	2.0	2.1	2.3	2.5
With				
Compost	1.9	1.9	2.5	2.3
Fertilizers	2.1	2.1	2.5	2.5
	Total plants per sq. yd.			
With				
Compost	860	890	960	810
Fertilizers	930	1060	1020	890

The results are summarised in Table 20 for the three seasons in which both first-year and second-year seedling crops were grown. At Wareham the best "first-year" Sitka spruce were after fallow and the best "second-year" Sitka spruce after lupins. In the "second-year" crops, fertilizers gave larger plants than compost each year. In five of the seven test crops, fertilizers gave more Sitka spruce plants than compost. On the average of all six (or seven) crops, differences due to rotational treatments were small, continuous Sitka spruce averaging 2.4 inches and the best rotational crop 2.6 inches.

At Kennington Extension the contrasts between rotations were even smaller than at Wareham. Fertilizers gave more plants and larger plants in six out of seven test crops. The "second-year" Sitka spruce crop at Kennington Extension in 1952 was almost a failure, the compost plots having only 250 plants per square yard with mean heights of 1.1 inches, and the fertilizer plots 450 plants per square yard with mean heights of 1.4 inches. No satisfactory explanation can be offered for this failure, though cockchafer damage was suspected.

SITKA SPRUCE TRANSPLANTS FROM SEEDLINGS GROWN AS FIRST AND SECOND CROPS AFTER GREEN CROPS OR FALLOW

Table 21 Means of two crops, 1951-52

Manuring of: Seedlings	Manuring of: Transplants	*Height in inches* — Kennington Extension (KE 62, 63) First crops	Kennington Extension (KE 62, 63) Second crops	Wareham (W 65, 66) First crops	Wareham (W 65, 66) Second crops
Compost	Compost	8.9	7.9	6.8	6.3
Compost	Fertilizers	8.8	8.2	7.4	6.6
Fertilizers	Compost	8.9	8.0	6.6	6.2
Fertilizers	Fertilizers	8.9	8.1	7.2	6.6

Seedlings from these preliminary rotation experiments were tested in extension experiments on one-plus-one transplants, with additional tests on compost and fertilizers in the transplant lines. The results in Table 21 show that at Wareham transplants receiving fertilizers were taller than those receiving compost. At both centres the transplants showed no differences from the various cropping and manurial treatments of the seedbeds. Some of the seedlings were also tested in forest planting experiments.

Although little may appear to have emerged from this experiment, it is of some practical importance to note that Sitka spruce was no better after green crops and one-year leys than Sitka spruce grown continuously or after a bare fallow. Further, on the average of all test crops at each centre, heights and plant numbers were greater with fertilizers than with compost. The experiment, as a whole, failed to provide any support for the common view that the maintenance of soil fertility in forest nurseries depends on the addition of organic matter by cropping or manuring.

New Rotation Experiments

A new series of rotation experiments was started in 1951 in new extensions to the research nurseries at Kennington and Wareham. The plots were designed to allow seedbeds to be made up normally each season and to prevent movement of soil between plots by cultivation operations.

The main series of experiments is on green crops, Sitka spruce seedlings and transplants and has three phases each year, one for each stage of a three-course rotation. The treatments are:

Phase 1. Lupins, rye, ryegrass, fallow, Sitka spruce seedlings and transplants (the latter from seedbeds with fertilizers or compost).

Phase 2. Sitka spruce seedlings and transplants.

Phase 3. Sitka spruce seedlings.

All phases. Compost or fertilizer.

Seedlings from phases 2 and 3 will be tested as transplants in adjoining experiments, with additional tests on compost and fertilizer in the transplant lines. In addition, there are supplementary experiments on continuous seedbeds and transplants, testing no manure, compost, fertilizers and both, with additional tests on the application of limestone at Wareham.

Each plot is isolated from its neighbours by undug strips to prevent movement of soil.

The treatments were necessarily incomplete in 1952, and the first full set of results for seedbeds will be obtained in 1953. The 1952 results for the second phase—first testing crop—are summarised in Table 22. At Kennington, Sitka spruce seedlings were larger after seedlings in the previous year, than after fallow, and much larger after seedlings than after any of the green crops, i.e. a second Sitka spruce crop was better than a first. The largest transplants were after bare fallow or Sitka seedlings. Seedlings and transplants were a little larger with compost than with fertilizers.

At Wareham the Sitka spruce seedlings showed only small differences from previous croppings. Transplants after fallow or green crops were about an inch larger than those after seedlings in the previous year. Fertilizers gave larger plants than compost.

SECOND-YEAR RESULTS OF NEW ROTATION AND CONTINUOUS SITKA SPRUCE EXPERIMENTS AT KENNINGTON AND WAREHAM, 1952

Table 22

	Height in inches			
	Kennington (KT 101)		Wareham (W 101)	
	1+0 seedlings	1+1 transplants	1+0 seedlings	1+1 transplants
Rotation experiments				
After				
Lupins	1.6	9.8	2.6	9.1
Rye	1.5	9.6	2.5	10.1
Ryegrass	1.3	9.7	2.7	9.4
Bare fallow	2.2	11.2	2.8	9.6
Sitka spruce seedlings	2.8	10.9	2.7	8.6
With				
Compost	2.4	10.8	2.5	8.7
Fertilizer	2.1	10.2	2.9	9.4
Continuous experiments	(KT 104/5)		(W 104/5)	
With				
No manure	2.3	—	0.3	—
Compost	2.8	—	2.3	—
Fertilizer	2.8	—	2.6	—
Both	3.1	—	2.7	—

The contrast between the two nurseries is well shown by the growth of Sitka spruce seedlings on completely unmanured plots in the continuous seedbeds, the mean heights being 2.3 inches at Kennington and only 0.3 inches at Wareham. At Kennington the relative effects of compost and fertilizers were different in the rotational and the continuous plots summarised in Table 22. No explanation can be offered for this difference.

Seed Cover Experiment at Wareham 1948-1952 (W 29)

After visiting a number of Conservancy nurseries in 1947 and analysing a large number of nursery soils and seed covers then in common use, we found that the soils were neutral or only slightly acid in many nurseries yielding unsatisfactory conifer seedlings. In several cases, it was clear that the harm had been done by using seed covers rich in calcium carbonate; in others,

liming materials had been applied for rotation crops or in making composts. On our recommendation the Forestry Commission abandoned calcareous covers and restricted the use of liming materials in its own nurseries. An experiment was started in 1948 on very acid soil at Sugar Hill nursery, Wareham, to test the residual effect of eight kinds of cover used for four successive crops of one-year Sitka spruce seedlings, and then followed in 1952 by Sitka spruce with a uniform non-calcareous cover on all plots.

Six of the seed covers were being used in normal practice in 1947; four of them were calcareous and two non-calcareous. We added a quartz from the St. Austell china-clay workings, on the grounds of its suitability, reproducibility and freedom from calcium carbonate. This cover has since become the standard one in all our experiments. We also added, for an extreme contrast, a leaf litter (generally from Norway spruce) used with the St. Austell cover.

The 1952 results for one-year Sitka spruce (with uniform cover) are summarised in Table 23, the covers being set out in order of decreasing soil acidity, as expressed in pH measurements made in 0.01 M. $CaCl_2$. On plots which had received calcareous covers for four years the Sitka spruce seedlings ranged from 1.3 to 1.7 inches, and had many of the features of seedlings raised in some of the so-called "worn-out" nurseries. By contrast, the plots which had received non-calcareous covers had healthy plants with mean heights from 2.1 to 2.3 inches in the fifth successive annual crop.

EFFECT OF SEED COVERS APPLIED FROM 1948 TO 1951 ON ONE-YEAR SITKA SPRUCE GROWN WITH A UNIFORM COVER OF ST. AUSTELL QUARTZ IN 1952, WAREHAM

Table 23

Seed cover 1948-1951	Mean height in inches 1952	pH measured in 0.01 M. $CaCl_2$ 1952
Non-calcareous		
Litter+St. Austell quartz	2.3	4.1
Leighton Buzzard sand	2.2	4.2
St. Austell quartz	2.3	4.4
Doncaster quartzite	2.1	4.4
Calcareous		
Sea grit from Porthcawl	1.7	5.6
Gravel from Ayton, Yorks.	1.5	5.9
Limestone chips from Tair Onen	1.5	6.2
Sea sand from Bude	1.3	6.5

On half of the plots in this experiment we had reduced an acid heathland nursery soil to the condition of a poor established nursery on agricultural land within four years, merely by using covers in normal use when the experiment was started. We had confirmed the urgency of our recommendations in 1947.

Soil Reaction and Growth of Conifers

In 1948 we also set up at Kennington Extension and Wareham four sets of large plots in which the soil reaction was altered regularly over a wide range by graded additions of aluminium sulphate or limestone. Each year these plots have been cropped with a number of conifers in drills. From 1951

there have been three beds in each plot to allow additional tests on the effects of ammonium sulphate and "Nitro-Chalk" used as top-dressings.

In 1952 all six species of conifer grew least well on the most heavily limed strips. Douglas fir and Japanese larch gave their tallest plants in strips with medium liming, but *Tsuga*, Sitka spruce, lodgepole pine and Corsican pine, grew best in more acid soils, without showing any pronounced optimum in soil pH value.

In plots with medium and high liming, ammonium sulphate gave larger seedlings than equivalent "Nitro-Chalk" in eleven out of twelve comparisons. This superiority of ammonium sulphate in nearly neutral soils is in harmony with the results of earlier experiments, and with the view that conifers profit from receiving some of their nitrogen as ammonia. Nearly neutral soils normally provide more nitrate than ammonia unless they have been treated with steam, formalin or other materials, known to destroy nitrifiers and many other groups of micro-organisms. We are testing the hypothesis that the accumulation of ammonia nitrogen by checking nitrification is an important factor in "partial sterilization".

It is difficult to acidify soils in a short period without the risk of leaving a dangerous excess of salts. An alternative method of using ammonium sulphate in a series of four dressings annually, with Sitka spruce as a test crop, was continued for four years at Old Kennington. In the drought year of 1949 the nitrogen fertilizers had no effect, but in each of the next three seasons ammonium sulphate gave more and larger seedlings than equivalent amounts of "Nitro-Chalk", which does not acidify the soil. The mean heights for three seasons were given in Table 34 of the Summary Report on 1951 Experiments (*Forest Research Report*, 1951, p.97). The mean heights for 1952 were close to those in 1951. On the average of four seasons the total numbers of plants per square yard were: no nitrogen 750, "Nitro-Chalk" 780, ammonium sulphate 920.

Compost, Fertilizers and Formalin

The third-season results of parallel experiments at five nurseries are summarised in Table 24. To save space only four of the eight combinations of treatments tested are listed. The experiments on three agricultural soils gave very poor stands on plots treated with compost. It is uncertain whether this was the result of late sowing followed by summer drought or of some accumulation of pests and diseases. The experiments will be continued for at least one more season. In 1952 at Old Kennington there were fewer plants on compost plots than on fertilizer plots. Although formalin increased mean heights and numbers of usable plants, it gave only moderate increases in total plant numbers. At Ringwood, compost gave smaller numbers of larger plants than fertilizer; formalin markedly increased heights, weights and numbers of usable plants, but slightly reduced the total number of plants. At Kennington Extension, compost gave far fewer plants than fertilizers; formalin greatly improved heights and number of usable plants on compost plots. At Bagley Wood, formalin increased heights on plots receiving compost.

On the average of five experiments, fertilizers gave about 100 more usable plants, and about 150 more total plants, per square yard, than did compost. Formalin increased numbers of usable plants by about 100 per square yard, but it had negligible effects on total plant numbers. In these experiments, as in many others, the principal effect of formalin was not to prevent deaths from damping-off and other soil-borne diseases and pests, but to make plants grow better.

EFFECTS OF COMPOST, FERTILIZERS AND FORMALIN ON ONE-YEAR SITKA SPRUCE SEEDLINGS AT FIVE NURSERIES: OLD KENNINGTON, RINGWOOD, KENNINGTON EXTENSION, BAGLEY WOOD AND WAREHAM; THIRD SEASON, 1952

Table 24

Expt. No.	K 42	R 32	KE 49	B 26	W 55	Mean
Mean height in inches:						
Compost	0.6	1.5	1.0	1.5	2.5	1.4
Fertilizer	1.1	0.8	1.7	2.1	2.6	1.7
Formalin+compost	0.9	2.9	2.2	2.6	2.7	2.3
Formalin+fertilizer	1.6	1.9	2.3	2.2	2.4	2.1
Usable plants (over 1.5 inches) per sq. yd.						
Compost	0	150	30	290	500	190
Fertilizer	30	50	300	560	580	300
Formalin+compost	30	260	180	590	490	310
Formalin+fertilizer	160	310	340	580	470	370
Total plants per sq. yd:						
Compost	120	330	290	810	620	430
Fertilizer	290	500	610	860	670	590
Formalin+compost	170	300	260	830	610	430
Formalin+fertilizer	360	470	450	890	610	560

Methods of Applying Formalin

In experiments on amounts and times of application, formalin increased the numbers of usable seedlings per square yard from 100 to 550 at Old Kennington, and from 120 to 440 at Ringwood. Winter applications gave better results than early spring applications, especially for the heavier rates. It may prove that winter applications would be safer and more convenient in practice. Experiments are being made with a wide range of times of application on uncropped land, in preparation for Sitka spruce sowings in 1954.

Formalin, Paraformaldehyde, Chloropicrin and Ethylene Dibromide

The practical use of formalin is limited by the difficulty and cost of applying the large volumes of water needed to drench the soil. The search for more concentrated materials was continued.

Paraformaldehyde, a solid polymer of formaldehyde, failed to increase heights and slightly reduced plant numbers, though it has occasionally given good results in other seasons.

Ethylene dibromide improved growth only at Ringwood, which is known to carry a much heavier population of nematodes than the other nurseries in which we make experiments. Dr. J. B. Goodey's examination of plants from experiments in the Ringwood nursery showed that formalin, chloropicrin and ethylene dibromide greatly reduced the numbers of the nematode *Hoplolaimus uniformis* on one-year Sitka spruce seedlings. There were also differences associated with manurial treatments. (In another experiment at Ringwood, transplants growing on untreated plots carried a heavy infestation of the same nematode, whilst those on plots treated with formalin were completely free from it).

Chloropicrin injected in 2 ml. doses at 9 inch centres gave excellent results in the three experiments in which it was tested, the mean heights exceeding those from formalin applied in February. At Old Kennington, chloropicrin increased the numbers of usable seedlings per square yard from 50 to 360 and

at Ringwood from 210 to 580. Chloropicrin is the only substance we have yet tested in pot and field experiments which has given results equalling or even exceeding those given by formalin. More tests are being made in 1953.

Samples of soil taken in March and in April from an Ampthill experiment showed that both fresh and incubated soils had more nitrate than ammonia where no formalin was applied, but much more ammonia than nitrate where formalin had been applied, in either or both of the years 1951 and 1952. The results for incubated soil are given in Table 25. Parallel soil samples were examined microbiologically by Miss L. M. Crump.

AMMONIA AND NITRATE NITROGEN IN SOILS FROM A FORMALIN EXPERIMENT AT AMPTHILL, SAMPLED MARCH AND APRIL, 1952

Table 25

Soil treatment		Nitrogen in parts per million dry soil after incubation	
1951	1952	As ammonia	As nitrate
None	None	1.4	3.8
Formalin	None	3.0	1.6
None	Formalin	3.4	0.9
Formalin	Formalin	3.0	1.0

Visual Symptoms

A chlorosis ascribed to magnesium deficiency at Bagley Wood and Ringwood was cured in 1952, as in 1951, by applying magnesium sulphate or dolomite to the seedbeds.

An unexplained symptom, termed "tip-burn", appeared in several of the Wareham seedbed experiments during hot spells in summer. In some experiments it was severe on fertilizer plots, but rare on compost plots. In others it was more severe after clover or lupins, with organic nitrogen fertilizer in the seedbed, and after non-calcareous covers. Typical plants are being examined in pot experiments and by chemical analyses.

We have already established that the value of composts depends very largely on the supply of nitrogen, phosphorus, potassium and magnesium. In most nurseries excellent plants can be grown, for several years at least, by supplying these four elements as inorganic fertilizers. The few cases in which compost gives better sizes or colours than fertilizers are of particular interest because they may reveal other deficiencies. The main merit of compost may be to reduce the risks of unknown deficiencies. The major nutrients can be given better as fertilizers, and there is little or no experimental evidence of any benefit from the organic matter in the compost.

Root Examination of seedlings

Dr. I. Levisohn examined a number of seedling samples sent to her under code numbers. Most of them exhibited mycorrhiza and a number pseudomycorrhiza. In a few an infection of uncertain type was just starting. We failed to find any general relation between the nursery treatments and types of infection.

At Rothamsted over two hundred plant samples were examined for broad morphological characters of the roots. Variation was considerable; but in 1952, as in 1951, there were indications that plants from formalin-treated plots

had more root hairs. In five experiments on compost, fertilizer and formalin, damage to taproots and extent of thickened dark roots ("boot-straps") were increased by the manures and reduced by formalin.

Transplant Extension Experiments

Each year one or more transplant extension experiments are carried out at six nurseries to test the performance of seedlings raised with contrasted treatments in the previous year. Even where differences due to seedbed treatments are reduced by "evening-up" in the transplant beds, it must be remembered that increased heights in seedbeds commonly mean increased numbers of usable seedlings. There may, in addition, be a few cases in which the full benefit from a seedbed treatment does not show until after transplanting.

A set of transplant experiments in six nurseries in 1952 tested seedlings raised in the same nurseries in 1951 in experiments comparing varied quantities of formalin, applied in the winter of 1950-51 or in the early spring of 1951. The results for the average of six nurseries are given in Table 26.

EXTENSION EXPERIMENTS ON SITKA SPRUCE TRANSPLANTS TESTING EFFECTS OF FORMALIN ON SEEDBEDS

Table 26 Means of experiments in six nurseries, 1952

Seedbed Treatment	*Height in inches*			
	One Year Seedlings	One-plus-one transplants		
		Initial	Final	Shoot Growth
No formalin	1.9	2.4	7.4	5.1
Formalin in winter 1950-51....	2.8	3.5	8.1	4.6
Formalin in spring 1951	2.9	3.7	8.4	4.7

Assessments shortly after lining-out were about half-an-inch higher than the means in the seedbeds, because only plants over 1.5 inches are taken, and there may be a tendency to select larger plants. Formalin increased the mean heights of seedlings by about one inch and those of transplants by a little less. Although there was some "evening-up" in the transplant beds, formalin treatments of seedbeds produced more and larger seedlings and, also, larger transplants.

In experiments at three old nurseries on agricultural land the effects of formalin treatment of seedbeds were about half-an-inch less in the subsequent transplants than in the original seedlings; but in the same experiments a small benefit from heavy winter applications of ammonium sulphate was increased in the transplants. Although the effect was small, it shows that transplants do not invariably "even-up".

At Ampthill seedlings were raised in 1951 in eight plots with formalin-treatment, and in eight without. Seedlings from each kind of treatment were lined out in 1952 within the same experiment in such a way as to allow comparisons of the effects of formalin treatment on the seedlings, with those of the effects of formalin residues on the transplant beds. The results for the transplants are given in Table 27.

EXTENSION EXPERIMENT ON 1+1 SITKA SPRUCE TRANSPLANTS AT AMPTHILL 1952, ON PLOTS WITH CONTRASTED TREATMENTS IN 1951 (Am 15)

Table 27

One Year Seedlings		Height of Transplants in inches		
From soil with	*into soil with*	Initial	Final	Shoot Growth
No formalin	No formalin	1.4	5.3	3.8
No formalin	Formalin	1.4	6.0	4.6
Formalin	No formalin	2.6	5.8	3.2
Formalin	Formalin	2.8	6.8	4.0

The larger seedlings raised with formalin in 1951 made smaller shoot growth than the smaller seedlings raised without formalin. Shoot growth for both kinds of seedlings was larger on plots which had received formalin in the previous season. The largest transplants were in formalin-treated soil in both years. There was little difference between transplants which had spent either their first or their second year in soil treated with formalin early in 1951.

Treatment of Transplant Beds

Formalin applied to transplant beds, about three months before lining-out, increased the heights of transplants in 1952 by 2.1 inches at Ampthill and by 3.0 inches at Ringwood. In a related experiment at Old Kennington a gain of 2.3 inches from formalin had been obtained in 1951, but in 1952, when the formalin treatment in the same experiment was deliberately delayed until one month before lining-out (to avoid interaction with another experimental treatment), the results were disastrous, most of the transplants on the formalin-treated plots being killed. A similar failure occurred in the spring of 1953 on transplant beds treated with chloropicrin at Ringwood. Such results show that treatments appropriate for seedbeds may be unsafe for transplant beds, presumably because the roots of the transplants occupy cold soil, whilst in the seedbeds there is time for leaching, decomposition and other changes to take place in warmer soil before the seedlings begin to grow.

A manuring experiment at Wareham, continued with repeated dressings annually from 1949, showed only small differences between three kinds of nitrogen fertilizer or between three kinds of phosphorus fertilizer. The average effects of the three major nutrient elements are given in Table 28.

EFFECTS OF FERTILIZERS ON 1+1 SITKA SPRUCE TRANSPLANTS AT WAREHAM (W 41)

Table 28

	Height in inches			
	1949	1950	1951	1952
Mean	8.5	11.5	9.1	7.9
Effect of				
Nitrogen	0.4	3.8	1.9	0.4
Phosphorus	0.5	0.5	0.5	0.6
Potassium	0.2	1.2	0.6	1.1

Phosphorus fertilizers gave small benefits each year. Nitrogen fertilizers gave considerable increases in the two seasons of best general growth. Potas-

sium fertilizer increased heights in the last three years and, in addition, had striking effects on the colours of the plants. In 1952, plots with nitrogen and phosphorus fertilizers, without potassium, had yellow chlorotic needles, a symptom of acute potassium deficiency which had previously been observed in this nursery in 1946, but not in the next five seasons. Normal potassium deficiency shows as a dull mauve tint. Such observations are a reminder that visual symptoms of a deficiency may depend on many concomitant circumstances, which are often unrecognized, and that the absence of any one symptom does not necessarily imply that the element concerned is being supplied in adequate amounts.

Forest Experiments Planted in 1947

The first forest planting experiments in 1947 included manurial experiments on one-plus-one transplants of Sitka spruce and Scots pine (in alternating pairs along rows) in two forests: Broxa, Langdale Forest, North Yorkshire, a strongly leached heathland soil under vigorous *Calluna*; and Dartmoor Forest, Devon, on a grassy site near farm buildings in one corner of a planting area otherwise under *Calluna* on peaty moorland over granite. The experiments tested two kinds of phosphorus fertilizer (Bessemer basic slag and Gafsa mineral phosphate) in factorial combination with tests on a nitrogen and a potassium fertilizer. A slowly acting form of nitrogen fertilizer (formalized casein) was chosen, but the results were complicated by the circumstance that the small amount of phosphorus in this fertilizer was sufficient to give notable increases in growth. The results of the 1952 assessments after six seasons in the forests are given in Table 29 for four treatments, selected to eliminate the disturbance due to phosphorus in the formalized casein. The two forms of phosphorus fertilizer gave almost identical results.

FOREST MANURING EXPERIMENTS ON 1+1 TRANSPLANTS PLANTED AND MANURED EARLY 1947, ASSESSED LATE 1952

Table 29

	Height in inches			
	Broxa (Br 8)		Dartmoor (Da 8)	
	Sitka spruce	Scots pine	Sitka spruce	Scots pine
No fertilizer	31	42	73	69
Phosphorus	56	57	81	67
Nitrogen, phosphorus	58	59	88	68
Nitrogen, phosphorus, potassium	64	60	87	66

On the poor *Calluna* site at Broxa, both species gave large responses to phosphorus, with small additional responses to nitrogen; the Sitka spruce showed a further improvement from potassium. At Dartmoor Forest, Sitka spruce showed responses to phosphorus and nitrogen, but there were no effects on the Scots pine.

Extension experiments on Sitka spruce planted in 1947 as one-year seedlings and one-plus-one transplants at Broxa and Dartmoor showed in 1952 only small differences between plants treated in the nurseries with composts or fertilizers.

Forest Experiments Planted in 1949

The fertilizer experiments in forest plantings of 1947 and 1948 had been

made with single rows of trees as unit plots. This gave maximum accuracy for a given area in the early years of growth, but the results would in time become uncertain, as neighbouring rows began to influence each other. From 1949 onwards most of the extension experiments have been set out in pairs of blocks, one manured in the year of planting and one unmanured, with the extension tests on single rows in each block. Such blocks may continue to indicate manurial effects after differences due to nursery treatments have ceased to show. By the end of 1952, differences remaining from organic manures and fertilizers in seedbed had become small and irregular.

The results of one set of "block manuring" experiments in 1949 plantings, assessed in 1952, are given in Table 30.

FERTILIZER TESTS ON ONE-YEAR SEEDLINGS AND ONE-PLUS-ONE TRANSPLANTS, PLANTED AND MANURED EARLY 1949, ASSESSED LATE 1952

Table 30

	Height in inches		
	Broxa	Kerry	St. Gwynno
Sitka spruce			
1+0 no fertilizer	17	19	26
1+0 with fertilizer	34	22	26
1+1 no fertilizer	25	34	42
1+1 with fertilizer	42	36	41
	Broxa	Kerry	King's
Scots pine			
1+0 no fertilizer	20	19	36
1+0 with fertilizer	31	22	33
1+1 no fertilizer	31	29	50
1+1 with fertilizer	39	31	49

Sitka spruce and Scots pine were grown as alternating pairs along rows at two of the forests and separately at two others. At Broxa the site was similar and near to that for the 1947 plantings; Mason's Bank, Kerry Forest, Montgomeryshire, carried a mixed vegetation with *Calluna* and *Vaccinium*, and suffered severely over several seasons from soil-wash on high, loose ridges; the Gwynno Forest plot, Glamorgan, was on Molinia turf over Pennant Grit; the King's Forest plot was on fairly acid dry grass heath on fine sand over chalk. The fertilizer was applied as two one-ounce pellets per tree, and had the composition 5 per cent N, 10 per cent P_2O_5, 5 per cent K_2O.

At Broxa the heights of Sitka spruce seedlings were doubled by fertilizers, and those of Scots pine increased by one-half. The manured Sitka spruce seedlings were much taller than unmanured one-plus-one transplants; the manured Scots pine seedlings were equal to unmanured one-plus-one transplants.

The Kerry Forest plants showed height increases of only two to three inches from fertilizers, and the seedlings lagged behind the transplants. At St. Gwynno Forest there was no benefit from fertilizers, and at King's Forest a small depression. In this series of experiments the fact that there was no gain from fertilizer on the two grassy sites may be due, in part, to greater competition

with the grass, which in King's Forest, in the first year, overgrew the seedlings on manured plots.

The large response to fertilizers at Broxa introduces some complications into the extension tests. It was noteworthy that some small seedlings grew very poorly without fertilizer, reaching in the extreme case, only 6 inches in four years, whereas with fertilizer similar seedlings reached 26 inches. By contrast, large seedlings from another nursery reached 22 inches *without* and 39 inches *with* fertilizer. Most of the extension experiments of 1949 were not large or precise enough to measure the interactions between nursery treatments and forest manuring.

Experiments on seedlings, testing different forms and methods of applying a normal agricultural compound fertilizer, showed that there was no advantage from applying it in notches, either as granules or as large pellets, over broadcasting it in patches from 6 to 12 inches from the trees. At Broxa all methods increased heights of Sitka spruce by about one-half, and of Scots pine by about one-quarter. There were negligible effects at the three other forests. In other seedling experiments there were, at Broxa, large responses to superphosphate on both species, with a small response to "Nitro-Chalk" on Sitka spruce; at Kerry Forest, small but statistically significant increases from superphosphate on both species; at St. Gwynno on Sitka spruce, and at King's Forest on Scots pine, small reductions by "Nitro-Chalk".

Forest Planting Experiments, 1951

Parallel sets of experiments were planted in 1951 in Coed Sarnau Forest, Radnorshire, at Red Lion Hill, between 1,500 and 1,650 feet, with *Calluna* and coarse hill grasses, and Pistyll, a very exposed site between 1,600 and 1,750 feet with *Vaccinium*, *Holcus* and other hill grasses. Many of the experiments at Pistyll were abandoned after the 1952 assessments, since about half of the seedlings had died through exposure and damage by rabbits or hares. When the plots were inspected in the summer of 1952 the bitten-off leaders of many seedlings were lying near the plants. These losses appeared to be independent of nursery treatments, but it was clear that one-year seedlings were unsuited for such hazards.

Seedlings raised at Wareham, Bagley Wood, Kennington Extension, Ringwood and Old Kennington (the first three with and without formalin, the last two all with formalin), planted at Red Lion Hill, early in 1951, gave the following mean heights by the end of 1952: compost 10.6 inches, fertilizers 9.3 inches, both 10.1 inches. This is the first set of data from experiments over several years in which compost-plants have given better growth than fertilizer-plants when tested in the forests. Similar experiments were laid down in 1952. Analyses showed that from 1950 to 1952 seedlings from fertilizer plots often had much less potassium than those from composts. The rates of potassium manures in seedbeds were increased in 1952 in many experiments.

In manurial experiments seedlings at Red Lion Hill showed a small gain from superphosphate, and transplants a small reduction by nitrogen applied as a slowly acting fertilizer prepared by treating hoofmeal fertilizer with formalin.

In "block-manuring experiments" there was a small response to fertilizers at Red Lion Hill and a very small reduction in height by fertilizers at Pistyll (Table 31).

Local stock plants (two-plus-one transplants) gave much smaller plants and a much higher proportion of deaths after two years in the forest than one-plus-one transplants from our experiments in several nurseries.

FOREST MANURING EXPERIMENTS AT COED SARNAU FOREST, PLANTED AND MANURED EARLY 1951, ASSESSED LATE 1952

Table 31

	Height in inches			*Percentage deaths*		
	1+0	1+1	2+1	1+0	1+1	2+1
Red Lion Hill						
No fertilizer	7.9	17.3	11.4	14	0	7
Fertilizer	8.9	20.1	12.7	15	0	7
Pistyll						
No fertilizer	9.7	21.0	13.8	49	1	18
Fertilizer	9.3	20.4	12.3	45	2	22

PARTIAL STERILISATION OF SOIL FOR DISEASE CONTROL

By Dr. S. D. GARRETT
Botany School, University of Cambridge

The investigation in progress is a continuation of that initiated by Dr. J. H. Warcup (1951), who found that in soil sterilized, or partially sterilized, by formalin, the fungus *Trichoderma viride* became the dominant soil fungus, and that this dominance persisted for a year-and-a-half or more after treatment. Since *T. viride* is known to behave, under certain conditions, as a parasite and antagonist of other fungi (due to the fact that some strains of this fungus produce the antibiotic gliotoxin and others produce the antibiotic viridin), it was of interest to determine whether a soil in which *T. viride* was the predominant fungus, following formalin treatment, would be less suitable for the establishment and activity of *reintroduced* root disease fungi than an untreated soil.

Dr. Warcup (1952) had shown that formalin treatment was effective in destroying *Pythium ultimum* and other pathogenic species of *Pythium* in forest nursery beds of Sitka spruce; these fungi are chiefly responsible for the damping-off or a subsequent slow root-rot of spruce seedlings, and they are fortunately particularly sensitive to the action of formalin. Following upon Dr. Warcup's departure to Australia, the investigation was continued by Dr. H. C. Smith, who has studied the behaviour of *Pythium ultimum* when reintroduced into soils treated by formalin after the formalin vapour has passed off, and the new fungus flora established. Since *Trichoderma viride* flourishes best in acid soils in which the antibiotics produced by it are most stable, it was decided to treat a series of soils adjusted by acid and lime, respectively, to a suitable range of pH values with a graded series of formalin dilutions. In this way, a series of soils was prepared showing widely different fungus floras, ranging from the diverse flora of untreated soil to a flora strongly dominated by *T. viride.* Suitable inoculum of the pathogenic fungus, *P. ultimum*, was then introduced, and its subsequent behaviour followed both by direct microscopic examination, and by periodical plantings of a suitable host seedling (cress and turnip seed-

lings were chiefly used, rather than Sitka spruce, for reasons of experimental convenience).

Contrary to expectation, *P. ultimum* was found to be most active, and to survive for longest, in those soils (acid soils receiving full-strength formalin) in which the dominance of *T. viride* was most pronounced. Conversely, *P. ultimum* tended to be least aggressive in untreated soils with the original microflora, and especially in alkaline untreated soils. This unexpected insensitivity of *P. ultimum* to the antagonistic effects of *T. viride* may be due to the fact that the resting oospores of *P. ultimum* are highly resistant to such antagonistic effects; when they germinate, the mycelium grows very rapidly and may reach and infect host seedlings before it can be affected by *T. viride*. This does not, however, explain the fact that *P. ultimum* is actually most active in soils dominated by *T. viride*. A simple explanation might be that antibiotics produced by *T. viride* tend to inhibit spontaneous germination of the resting oospores of *P. ultimum* and hence to increase the longevity of the fungus in soil. Dr. Smith has, however, produced evidence in support of a more complex situation. He has shown that *P. ultimum* is particularly sensitive to the antagonism and competition of certain soil bacteria, and especially to that of certain gram-positive bacteria. These bacteria seem particularly sensitive to formalin treatment of soil and to the antagonistic effects of *T. viride* that follow this treatment.

Dr. Smith's conclusions thus reinforce those of previous workers with many different root disease fungi, viz. that the natural biological control exerted by the microflora of untreated soils is greater than that operative in partially sterilized soils. In consequence, strict precautions must be maintained against recontamination of partially sterilized soil by pathogenic fungi, at least until the earlier phases of microfloral recolonization are over.

Mr. E. Evans is engaged upon a related problem. It has been claimed by Bliss (1951) working in California that fumigation of citrus orchard soils with carbon disulphide is effective in eradicating *Armillaria mellea* from infected citrus roots, not because of any direct action of the fumigant upon *A. mellea*, but because fumigation (like the formalin treatment above) produces a dominance of *Trichoderma viride* in the soil. Bliss has suggested that, as *A. mellea* is not killed when infected citrus roots are fumigated in sterile soils, the killing action is due not to a direct effect of carbon disulphide upon *A. mellea*, but to the action of the much increased population of *T. viride*. Attractive and potentially important though Bliss's hypothesis is, it cannot yet be considered as proven, and it is possible that carbon disulphide has an effect in lowering the resistance of the *A. mellea* mycelium to attack by *T. viride* and other microorganisms. Mr. Evans is at present experimentally testing these various possibilities, and is using, as test material, pine wood infected with *Fomes annosus*. Dr. J. Rishbeth (1952) has shown how *F. annosus* can be prevented from establishing itself in new pine plantations in the first instance, i.e. by paint protection of stumps after felling; the second problem, i.e. how to deal with such a fungus in old infected roots, is still vexing foresters and plantation managers all over the world, and this now remains the central problem of root disease control in all plantation crops.

REFERENCES

Bliss, D. E. (1951) *Phytopathology* 41, 665.

Rishbeth, J. (1952) *Forestry* 25, 41.

Warcup, J. H. (1951) *Trans. Brit. Mycol. Soc.* 34, 519.

Warcup, J. H. (1952) *Ibid.* 35, 248.

RESEARCHES IN SOIL MYCOLOGY

By Dr. IDA LEVISOHN
Bedford College, London University

The Rhizosphere Effect of Mycorrhizal Mycelia

Mycorrhizal work at Bedford College is, at present, not so much concerned with the study of the actual mycorrhizal association, but concentrates more around the study of the activity of mycorrhizal mycelia and their effect on root and shoot development in the absence of an association with the roots.

Previous experiments (*Report on For., Res.* 1952) have demonstrated that leachings from 'mycorrhizal' soils can induce profuse root forking of actively growing Scots pine seedlings without causing a root infection. These findings have lately been confirmed for other pine species and for different types of 'mycorrhizal' soils. Furthermore, results of experiments in which various kinds of 'pseudomycorrhizal' soils were used, provided additional evidence that pine roots growing in the leaching water from such potting media also respond by forking. These branched roots exhibit, however, a pronounced pseudomycorrhizal infection, thus contrasting with the reaction in leachings from 'mycorrhizal' soil.

The cause of this differential behaviour is not known at present. It is suggested that the contrasting response might be due to a different mode of root infection, or that the reaction of the mycelia to aquatic conditions might be decisive. In order to test the latter point and to elucidate whether aeration is a factor limiting the growth of mycorrhizal mycelia or the formation of a mycorrhizal association, the leaching water from a mycorrhizal soil in which pine roots were growing, was aerated during the summer and autumn. Though profuse forking of the short roots was recorded, no root infection was observed.

It will be the task of further investigations to enquire into the mode of root infection produced by mycorrhizal and pseudomycorrhizal fungi, about which nothing definite is known.

While pine roots rapidly respond by forking when they are grown in leachings from natural soils, complete lack of reaction was recorded when pine seedlings, grown in a partially sterilized potting medium, were watered with leachings from various kinds of soil. The leaching water obtained from 'mycorrhizal' and 'pseudomycorrhizal' soils—some of these soils unplanted and some carrying Scots pine—was passed through a Berkefeld Filter before application. At the end of the second growing season, no difference could be observed in shoot and root development of treated and control plants.

The failure to obtain a differential response in the series of this experiment, may be due to the following factors:—1. The effective fungal exudates might have suffered absorption by the Berkefeld Filter or by the particular potting medium used (sand+compost). 2. The stability of the exudates might be inadequate to survive the long 'handling'. With these considerations in mind, an experiment on different lines was planned.

In order to test the effect of mycorrhizal fungi on roots growing in natural soils, endotrophic tree species were raised in pot-cultures and ectotrophic mycelia used as inoculum. Thus the formation of mycorrhizal associations was avoided. For these investigations, mycorrhizal roots were found to be

the most suitable inoculating material. After surface sterilization with mercuric chloride, fragments of pine mycorrhizas were introduced into a potting soil which was free from both the introduced mycorrhiza-former and the mycorrhizal associate of the test plant. The soil was sown with Lawson cypress, an endotrophic species. Control series comprised the following sets:—

(*a*) Absolute control, potting soil not inoculated;

(*b*) Potting soil inoculated with non-mycorrhizal pine roots (for the purpose of the experiment pine seedlings had been raised aseptically);

(*c*) Potting soil inoculated with sterilized mycorrhizal pine roots.

The cultures treated with an inoculum of active mycorrhizal material produced Lawson cypress seedlings far superior in height to the seedlings of the three control sets. There was no root infection observed in either of the experimental plants.

These experiments demonstrate that an ectotrophic mycelium can produce a stimulating effect on shoot development of an endotrophic tree species although not going into partnership with the roots. No instance of the reverse relationship, the stimulation of an ectotrophic tree species by an endotrophic mycorrhiza-former has been recorded so far.

Pot-culture work applying the method of root cross-inoculation is now being extended to certain selected tree species, among these *Ailanthus*, a tree which has not been observed to possess the mycorrhizal habit. In addition, the effect of ectotrophic mycorrhizas on endotrophic crops like *Allium*, and non-mycorrhizal families like the cruciferae, will be tested in further experiments.

EFFECT OF TREE GROWTH ON SOIL PROFILE DEVELOPMENT

By T. W. WRIGHT

Macaulay Institute for Soil Research, Aberdeen

The work at Culbin Forest, Morayshire, has been completed, and the results embodied in a thesis submitted to the University of Aberdeen. This traces the development of a soil profile in the Culbin sand dunes after their fixation and afforestation; the results may be summarized as follows:—

Mechanical Analysis

Appreciable variation in the mechanical composition of the sand on unplanted dunes has been shown to occur as the result of topographical irregularities. Similar variations observed in the sample plots have therefore been ascribed to topographical differences rather than the effect of tree growth. After the closure of canopy, however, downward percolation of organic matter initiates the formation of an A_1 horizon, which considerably reduces the effective mean grain size in the surface layers. It appears that this occurs more easily under Corsican pine and birch; Scots pine tends to form a thick, felted A_0 horizon which does not mix readily with the underlying sand.

Moisture Studies

Gypsum moisture blocks have proved most effective in the detection of the wilting point. Actual quantitative measurements of soil moisture to

supplement the information from the block readings have been made with the 'Speedy' moisture tester, an accurate and fairly rapid field method.

The results show that the unplanted dunes do not dry out in summer to a depth of more than about two inches, which corresponds roughly to the capillary rise in a soil of this coarse texture. Continued drying after this limit has been reached ruptures the moisture film in the pores at this depth, so that removal of moisture from deeper layers is limited to the rate at which vapour transfer can take place across this dry zone. Since this is very slow compared with liquid flow, little further drying occurs until such time as rainfall re-wets the whole profile. This peculiarity of extremely sandy soils means that at least part of the root systems of newly planted trees is in soil which never dries out, and accounts in part for the very satisfactory survival rate at Culbin on what would appear to be a most unpromising site.

The growth of trees on the dunes removes large quantities of water by transpiration, forming critically dry layers whose depth and extent varies with the age and root development of the species concerned. Of the plots studied, moisture deficiency is most acute in the twelve-year-old Corsican pine, which have not yet fully closed canopy and whose rooting depth is still comparatively shallow. The formation of humus beneath the older trees considerably improves the moisture status of the surface soil, except in the case of the Scots pine, whose poor development of an A_1 horizon has been noted. Dry layers at the lower rooting depths, however, were detected by the beginning of July in all plots bearing trees. Comparison of soil moisture content in plots thinned to different grades shows that moisture deficiency can be reduced by heavier thinnings, provided that the surface soil is protected from wind erosion by adequate thatching.

Temperature measurements with the thermistors in the surface sand show that a low, dense cover of heather and its associated mosses and lichens is the most efficient thermal insulator of the soil, and thatch appears to be almost as good in this respect as the twelve-year-old Corsican pine.

Chemical Analysis

Chemical analysis of the soil in the sample plots shows that as soon as the sand is stabilised, profile development by leaching begins. Thatching is beneficial from the chemical as well as the physical point of view, since within two years it adds appreciable quantities of phosphate, potassium and manganese. The growth of vegetation on the dunes initiates a circulation of nutrients, which is superimposed on the downward leaching. Nutrients are removed from depths depending on the rooting depth of the trees, and a proportion is returned to the surface in the litter. The greatest decrease is found under the younger trees; after the closure of canopy enrichment of the surface soil from the litter begins, and under the older pines the surface soil has a considerably higher nutrient content than the bare sand, although a decrease at the rooting depth is still discernible.

The lowest nutrient content of all the tree plots was found under birch; the dunes are too dry for this species, its litter fall is much reduced, and it competes with the pines for nutrients without returning an appreciable amount to the soil. Under these circumstances its encouragement as an 'improver' species is not considered advisable.

The phosphate content of the Culbin soil is extremely low, the total phosphate averaging about 200 parts per million. It is proposed to set up a small phosphate manuring experiment to test the effect of ground mineral phosphate on the growth of young trees.

Incubation of the surface soil from plots bearing trees shows that the rate of ammonification tends to increase with the age of the crop, but that it is more rapid under Corsican than Scots pine; production of nitrite or nitrate during incubation was not observed.

Other Work

The experimental apparatus for the detection of soil moisture by neutron scattering was completed, and shown to be capable of recording the moisture content of a garden soil under laboratory conditions.

GROWTH AND NUTRITION OF SPRUCE AND PINE IN HEATHLAND PLANTATIONS

By Dr. L. LEYTON
Imperial Forestry Institute, Oxford

Experiments begun in 1949 on the growth and nutrition of Sitka spruce and Corsican pine (Wykeham, Allerston Forest, Yorkshire) and of Sitka spruce and Scots pine (Clashindarroch, Aberdeenshire) have now been completed. (For details, see *Annual Reports on Forest Research*, 1950, 1951, and 1952.) The following conclusions have been drawn :—

(1) The most important nutritional factor limiting the growth of the spruce in the Yorkshire plantations is a deficiency in available nitrogen. An increase in the nitrogen status of the trees followed by an improvement in height growth may be obtained at least temporarily by removing the heather vegetation surrounding the trees (screefing). Other measures such as the application of nitrogenous fertilizers or heather mulching effect a similar response. In the absence of the heather, where nitrogen is no longer deficient, calcium tends to become a limiting factor. In the Clashindarroch plantation nitrogen and calcium are also deficient, but manganese may also play an important role since measures which lead to a stimulation in growth (viz. screefing and heather mulching) also result in an increase in the manganese concentration in the needles.

(2) There is no evidence that the soil phosphate is deficient and limiting the growth of the spruce, though the trees show a rapid response to the application of ground mineral phosphate in so far as the phosphate concentration in the needles is concerned. Only where available nitrogen is no longer deficient (e.g. in the absence of the heather) does the phosphate fertilizer tend to stimulate growth. The beneficial effects of fertilizers like basic slag must be attributed partially to their lime content and to their influence on microbiological activity in these soils.

(3) Both Scots and Corsican pine appear to be less affected than spruce by mineral nutrient deficiencies in the heathland soils, though in the latter case the removal of the heather vegetation also effects an improvement in the nitrogen status of the trees and a stimulation to growth.

(4) The removal of the ground vegetation may, in periods of dry weather, lead to excessive desiccation of the upper layers of the soil and thus adversely affect the activities of the superficial root system of the spruce. Pines, being generally more deeply rooted, tend to be less affected; but in the Clashindarroch

plantation, possibly because of increased exposure, the Scots pine have suffered a certain amount of damage following the removal of the heather.

(5) The concentration of nitrogen in the current needles of the spruce and in the current foliage of the heather plants surrounding the trees are significantly correlated with each other, suggesting that both tree and shrub respond in a similar way to variations in the supply of available nitrogen in the soil. This must be associated with the fact that both spruce and heather exploit the same horizons in the soil (mainly the upper raw humus layer) and tends to explain the pronounced influence of the heather on the growth of the spruce. The relationship between these two species has been further extended by the discovery of a significant correlation between the height growth of the spruce and the nitrogen status of the *Calluna* plants in the vicinity. This may prove of some value in the assessment of the potentialities of a heathland site for the growth of spruce.

THE FOREST ECOLOGY OF ACID SOILS

By Dr. G. W. DIMBLEBY
Imperial Forestry Institute, Oxford

Since the last report two years ago, the preliminary conclusions briefly outlined therein have been published in detail in a series of papers (see below), and others are in the course of preparation. The work in progress now is aimed at determining more precisely the essential features of the equilibrium between vegetation and soil which must be the basis of ecologically sound long-term forestry. It is probably true to say that in this country we have no remnant of the original forest—acid soil complex in a stable form, most of it having been changed to heath, moor, hill peat, etc. This, in the writer's opinion, has given rise to serious misconceptions about the fundamental principles of the natural balance. Since no direct approach to the problem is possible, the lines of work must be devious and may even appear to the superficial glance to be irrelevant. Briefly they may be classified under two heads:

(*a*) Historical researches; an attempt to gain a more precise knowledge of the structure and composition of the original forest on acid sites.

(*b*) Observations on the influences of different species and mixtures on soil processes today. If we can assess the relative powers of species (including those of the shrub and herb layers) as soil improvers or degraders, this will be valuable in interpreting the structure of the early forest, and so giving a line on the main problem of equilibrium. In addition, of course, a knowledge of the effect of different species on the soil is of immediate practical value. One of the problems here is to measure the relevant soil changes, and enquiries aimed at this are being undertaken.

It has been found essential to check the history, both recent and long-term, of all sites studied, in order to avoid misleading correlations between the present vegetation and soil type, and here the technique of pollen analysis of mineral soil has proved invaluable and sometimes very revealing. This technique can only be applied to acid soils, but fortunately all the sites so far encountered allow its use.

These researches into the ecological equilibrium are being pursued in close co-operation with the other members of the Oxford team. The close agree-

ment reached by the extensive (ecological) and intensive lines of approach (especially those of Dr. W. R. C. Handley), is evidence of the fundamental importance of such studies, and convinces us that sooner or later foresters are going to need more data on this question than are available at present.

In the last report (1950) it was mentioned that certain field experiments relating to the improvement of heathland soils by hardwoods had been started. These have continued and have been extended, and some striking results are already to hand. Over forty species of hardwoods have been sown on Broxa Moor (Allerston Forest) and the great majority have shown unexpectedly good survival. Growth of the oldest seedlings at the end of their third year was in many cases most promising, and on a par with good nursery stock of the same age. In an experiment designed to test the effect of birch litter on unploughed soil, with and without heather screefing, noticeable changes have already come about, including the appearance of earthworms. It is hoped to produce soon a short account of the more important of these findings for publication.

By the very nature of this work, factual reports of progress cannot be produced at regular intervals, but this interim account may serve to indicate the general trend of the work in hand.

PUBLICATIONS

1. The Root Sap of Birch on a Podzol. *Plant and Soil.* IV.2. 1952.
2. Soil Regeneration on the North-east Yorkshire Moors. *J.Ecol.* XL.2. 1952.
3. The Historical Status of Moorland in North-east Yorkshire. *New Phytol.* LI.3. 1952.
4. Natural Regeneration of Pine and Birch on the Heather Moors of North-east Yorkshire. *Forestry.* XXVI.1. 1953.

THE PHYSICAL AND CHEMICAL PROPERTIES OF FOREST SOILS

By P. J. RENNIE
Imperial Forestry Institute, Oxford

Progress during the past year on the soils of the Allerston Forest Area is outlined below.

Investigations Within a Mature Pinewood

Early in 1952 it was learned that the woodland known as Turkey Carpet Plantation, Suffield Moor, was to be clear-felled. This wood was unique in being the only known area in Allerston Forest, Yorkshire, of predominantly pure mature Scots pine in closed canopy on a podzolic soil, known to have been moorland before 1820, and derived largely from the Lower Calcareous Grit. A survey of the plantation showed that representative soil profiles could be extracted not only from Scots pine sites, but from under birch, beech

and oak, all of which were over fifty years old, and also from a heather-dominated site where growth of all tree species had failed.

The soil and vegetation studies are at present continuing, but certain interesting points have become apparent:

(*a*) the podzolic soil has been derived largely from the Lower Calcareous Grit, but an Older Glacial Drift has given rise to a small distribution of erratic pebbles throughout the soil profile to a depth of, at least, 70 cm. (about 28 inches).

(*b*) the site of the wood is a geologically marginal area, the soil ranging from the stoneless coarse sand derived from the Passage Beds (as on Brompton Moor, Allerston Forest) to the very stony sandy silt derived from the Lower Calcareous Grit (as on Hackness Moor).

(*c*) the distribution of beech and birch was related to the geology and the topography. Beech, of moderate growth quality, was confined to a gentle stony slope of high silt content and very weakly developed ironpan. *Oxalis acetosella* was present in the ground vegetation. Birch, always of poor growth, was confined to almost stoneless fine sandy sites of a typically low coarse sand and silt content. The ground vegetation ranged from dense to sparse *Deschampsia flexuosa*. Holly appeared tolerant of both stoneless and stony sites, whilst good quality sessile oak was found on soils which differed least in their particle size distributions from those of Hackness Moor. The European larch present formed approximately 15 per cent of the stand (stem counts) but appeared to be distributed fairly evenly throughout the Scots pine.

(*d*) Annual incremental growth curves, based on measurements of a number of the older representative Scots pine, showed that steady growth of approximately Quality Class II had been maintained for the first 50 years. Growth during the next 25 years, however, had fallen off markedly. The form of the incremental growth curve during the first 30 years was almost identical to that of Scots pine notch-planted into a heather-dominated podzol, derived from the Lower Calcareous Grit of Brompton Moor (Wykeham Compartment 56).

(*e*) Notable differences have been recorded between the amounts of litter that have accumulated under the various species, the figures in metric tons of oven-dried material per acre being: sessile oak, 9.4; beech, 7.5; birch, 7.1; holly, 5.4 and pine, 14.9.

(*f*) The litters under the various species differed in acidity, the following "pH" values being recorded for 1 : 5 KCl and H_2O suspensions respectively; sessile oak, 3.2 and 3.6; beech, 3.2 and 3.7; birch, 2.7 and 3.2; holly, 3.9 and 4.3 and pine 2.5 and 3.0.

(*g*) Examination of the profile morphology showed that rooting of all species was predominantly within the litter and raw humus layers, sometimes with a secondary zone of rooting development within a laminated humus horizon above the ironpan. Where the ironpan was of average depth i.e. about 25 cm., a proportion of roots exploited a brownish fawn zone some 10 cm. (4 inches) thick below the ironpan, a zone which has been found, on Silpho Moor, to possess the higher porosity of the bleached horizon, compared with the subsoil, and the higher "aeration" of the subsoil, compared with the bleached horizon.

(*h*) Porosity and aeration studies showed that prolonged forest cover had increased porosity very little compared with the heather-dominated Silpho

Moor. Increased aeration was due primarily to a reduced moisture content, not improved structure. Differences in porosity and aeration between species were reflections of site heterogeneity, similar to those recorded between soils derived from different geological strata supporting a similar vegetation.

(*j*) The effect of prolonged predominant coniferous growth had produced a marked change in the former heather raw humus.

Although appearing to be of similar thickness to raw humus under living heather, it possessed, in the water-free state, an apparent density of 0.2 instead of 0.4 grams per millilitre.

(*k*) The open site supporting dominant heather possessed a strongly developed ironpan at the atypical depth of 70 cm. (28 inches). The bleached horizon was very poorly aerated, the site and soil possessing many characteristics, except the vegetation, of the "closed basin" ironpan areas of Silpho and Brompton Moors (Wykeham Compartment 56) which support cotton grass, *Eriophorum* spp., and blue moor grass, *Molinia caerulea*, respectively, but not tree growth in the uncultivated condition.

Soil Phosphorus

Studies on soil phosphorus have been in progress, concerned both with the total P in soil, and the partial fractionation of soil P compounds according to a modified procedure developed from C. H. William's separation (1950, *Journ. Agric. Sci.* 40, 233-242).

Certain interesting results so far are :—

(*a*) The amounts of total P in a podzolic moorland soil supporting heather, and an alluvial valley soil, may be similar, e.g. for the uppermost 25 cm. (10 inches): 291 and 305 kilograms P per acre respectively. There may also be not a large difference between the "easily soluble P" (soluble in 8-hydroxyquinoline in acetic acid) calculated for the same depth, i.e. 25 and 29 kilograms P per acre respectively; the percentages of P existing in "readily soluble" form of the total present, for the same depth, are 8.5 and 9.5 respectively.

(*b*) The distribution of total P down the soil profile in the podzol and in the alluvial valley soil differ markedly. For the podzol the total P as kilograms per acre per centimetre of depth varies as follows: raw humus, 9.0; upper bleached layer, 5.7; lower bleached layer, 13.2; humus ironpan, 20.1; subpan, 14.5; subsoil, 12.3; but the values for the top 60 cm. (24 inches) of the valley alluvium change gradually from 12.2 to 10.4.

(*c*) The distribution of "easily soluble" P down the profile differs even more markedly, the values for the podzol being in kilograms per acre per centimetre of depth: raw humus, 2.7; upper bleached layer, 0.47; lower bleached layer, 0.63; humus-ironpan 0.42; sub-pan, 0.15; sub-soil, 0.12; the two latter values being 1 per cent of the total P.

For the valley alluvium the values change only slightly, the values at the top and bottom being 1.39 kilograms per acre per centimetre of depth. This represents 10 per cent of the total P present.

(*d*) The expression of the data as kilograms of P per acre per centimetre of depth instead of as milligrams of P per gram of oven-dry soil, allows a more relevant picture of the distribution of P to be obtained. For example, at Harwood-dale Moor, the distribution of P is as shown in Table 32.

DISTRIBUTION OF PHOSPHORUS IN VARIOUS DEPTHS OF SOIL AT HARWOOD-DALE MOOR, ALLERSTON FOREST

Table 32

Depth	Horizon	Total Phosphorus	
		Milligrams per gram of oven-dried soil	Kilograms per acre per centimetre of depth
0 — 5 cm	dark brown peat	0.290	6.4
5— 12 cm	greyish brown loam	0.120	6.1
12—20 cm	dark grey loam	0.137	6.9
20—29 cm	grey-fawn mottled loam	0.118	6.4
29—34 cm	„ „ „	0.105	6.2
34—40 cm	„ „ „	0.100	6.2
40—50 cm	grey loam	0.092	6.0

Much of the research carried out to date is being included in a detailed omnibus report now in preparation.

SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY

Rothamsted Experimental Station, Harpenden

The writer is engaged in analysing and collating the data obtained in an investigation of the meio- or meso-fauna of a heathland habitat in the Allerston Forest area, North-east Yorkshire.

The main project has been a soil faunal survey of natural and afforested heathland. The fauna were extracted with a split-funnel extractor, a modified Berlese funnel. The sampling method consisted in taking blocks of soil, raw humus, or litter, from heathland and forest sites, and cutting cores which were placed in the funnels, in an undisturbed condition.

An examination of the funnel method of extraction was carried out in order to test the efficiency of the method. Best results were obtained when litter and raw humus were extracted separately, the latter in thin layers in an undisturbed condition. There was little difference between room temperature and a heated funnel (air temperature 30 to 35°C.=86 to 95°F.) for extraction of litter, although with raw humus the heated funnel was more effective. Poorest results were obtained when litter and raw humus were not separated, and the raw humus disturbed before extraction. It was found that the time at which organisms leave raw humus is correlated with rate of desiccation of the sample, which in turn is a function of volume of extraction material, and therefore depth of subsample. Disturbed samples are the slowest to dry and the population takes the longest time to leave these samples. It should be stressed that these findings were obtained with *Calluna* heathland samples and do not

necessarily apply to other habitats. The results of this investigation are to be published shortly.

NUMBERS OF ACARINA AND COLLEMBOLA OCCURRING IN SIX SAMPLES TAKEN IN CLOSE PROXIMITY TO ONE ANOTHER

Table 33 Sample size 17.8 sq. cm. x 4 cm. deep

Sample	Acarina					Collembola
	Mesostigmata	Trombidiformes	Oribatoidea	Undetermined and other Acarina	Total Acarina	
1	4	185	96	3	288	58
2	4	289	106	7	406	87
3	4	19	68	2	93	51
4	3	32	46	6	87	22
5	8	59	55	—	122	37
6	4	56	83	16	159	69

MEAN NUMBERS OF ACARINA AND COLLEMBOLA IN THE LITTER AND RAW HUMUS OF THE SIX SAMPLES OF TABLE 33 ABOVE

Table 34

	Acarina	Collembola	Total
Litter	118	39	157
Raw humus	75	16	91
Total	193	55	248

Sampling of the natural, undisturbed heathland indicates that the numbers of Acarina can fluctuate widely even over a small area. Tables 33 and 34 summarise the populations obtained from six circular samples of litter and raw humus, with areas of 17.8 sq. cm. and 4 cm. deep, distributed in two rows of three, with intervals of 10 cm. between sample centres. The populations range from 87-406 Acarina per sample. Part of the increased population occurring at one end of the block is due to a massed occurrence of very small mites belonging to the genus *Tarsonemus*.

In the investigation of extraction method, a technique was devised for reducing the inherent variation between samples, and it is possible that a development of this method may offer a means of overcoming some of the problems of estimating populations in litter and raw humus substrates. As Table 33 indicates, aggregates of Acarina may be very marked even over a small area; if however the sample block is kept for two to three days at a moderate temperature before the sample core is cut and extracted, a certain amount of drying takes place which causes the fauna to move away from the edges of the block. The resultant concentration of fauna will tend to iron out local aggregations. The violent fluctuations in population numbers, and the large number of samples necessary to indicate population levels, is the crux of soil faunal surveys, and any method which reduces the number of samples to be examined will greatly aid such investigations. Because of these difficulties, this method is tentatively suggested although much more work is necessary before it can become a practical proposition. Again it must be stressed that this procedure may not be suitable for other habitats. Indeed

ACARINA SPECIES RECORDED FROM NATURAL AND CULTIVATED HEATHLAND PLANTED WITH SITKA SPRUCE

Table 35

	Natural Heathland	Cultivated Heathland planted with Sitka spruce
MESOSTIGMATA		
Pergamasus alpestris Berl.	+	Mesostigmata fauna not examined in detail
,, *crassipes* (Linn.)	+	
,, ,, var. *longicornis* Berl.	+	
,, *robustus* (Ouds.)	+	
,, *runcatellus* Berl.	+	
,, *runciger* Berl.	+	
***Zercoseius pavidus* (Koch)	+	
Arctoseius cetratus Sell.	+	
Olodiscus minima (Kram.)		+
HETEROSTIGMATA		
Diversipes exhamulatus (Mich.)	+	
** ,, (*Microdispus*) *obovatus* Paoli	+	
Imparipes sp.		+
Pygmephorus tarsalis Hirst	+	
Tarsonemoides brevilobus Weis-Fogh	+	
Tarsonemus sp.	+	
ENDEOSTIGMATA		
Alicorhagia fragilis Berl.	+	+
Nanorchestes arboriger Berl.	+	+
PROSTIGMATA		
Cocceupodes clavifrons (Can.)		+
,, *curviclava* Thor		+
Protereunetes sp.		+
Coccorhagidia subterranea (Berl.)		+
†*Coccorhagidia* n. sp.		+
Stigmaeus sp.		+
Ereynetes sp.	+	
***Coccotydeus tenuiclaviger* Thor	+	
Lorryia sp.	+	
**Microtydeus* sp.	+	
Tydeus sp.	+	+
**Eupalopsis ? pini* Can.	+	
Petrobia sp.	+	
Balaustium sp.	+	
CRYPTOSTIGMATA		
†*Schwiebia* n. sp.	+	
Nanhermannia nana (Nic.)		+
Brachychthonius cricoides Weis-Fogh		+
,, *marginatus* Forss.	+	
,, *perpusillus* Berl.		+
,, *piluliferus* Forss.	+	
,, *sellnicki* Thor	+	
,, *simplex* Forss.		+
,, *zelawaienis* Sell.		+
Camisia exuvialis Grand.	+	+
Nothrus silvestris Nic.	+	+
Ceratoppia bipilis (Herm.)	+	+
Oppia nova (Ouds.)	+	+
,, *ornata* (Ouds.)	+	+
Oribella lanceolata (Mich.)	+	+
Suctobelba subcornigera Forss.		+
Carabodes marginatus (Mich.)	+	
,, *minusculus* Berl.	+	+
Tectocepheus velatus (Mich.)	+	+
***Chamobates shütz*i (Ouds.) (non auct.)	+	+
Melanozetes mollicomus (Koch)	+	
***Phthiracarus anonymum* Grand.	+	
Pseudotritia ardua (Koch)		+

**New British records for species. *New British records for genus. †New species.

the faunistic composition of this particular sample site, with few species occurring, suggests a homogeneous habitat with few "niches", and the aggregation pattern may be comparatively simple. Under these conditions, a factor such as moisture content may dominate other attributes affecting aggregation and dispersion. In more diversified habitats alteration of one such factor may not have the desired effect.

Numbers of organisms can give a very misleading picture of the fauna of a particular habitat. What is more important is a functional outlook, and for this purpose the volume of living material is a more valuable measure. However the obvious goal of the investigator is a metabolic yard-stick such as respiration rate. The writer has not yet attempted to determine biomass* values, but it is possible to obtain from the literature, an approximate comparison of the amount of living material present in contrasting soil habitats Murphy, (1953). Van der Drift's (1950) and Salt's (1948) data suggest the following proportions—expressed as volumes—for the Acarina and Collembola fauna:

The litter layer in the forest, about 1:30,000
Raw humus, about 1:10,000 -20,000 } (After Van der Drift, 1950)
Grassland to 12 inches depth, about 1:20,000 (After Salt, G., 1948)

A total of 53 species of Acarina have been recorded from natural heathland and forest plantings in the Allerston area. Table 35 lists the species and indicates their occurrence in natural heathland and cultivated heathland planted with Sitka spruce. This list includes two new species, two new British records of genera (*Microtydeus* and *Eupalopsis*) and five new specific records. In the natural and undisturbed heathland the most common and abundant species are *Nanorchestes arboriger* Berl. (Endeostigmata), a small, active, saltatorial mite, *Carabodes minusculus* Berl., *Tectocepheus velatus* (Mich.) and *Chamobates* sp. (Oribatoidea). When compared with other habitats the most striking feature is the small size of the heathland species. It is noticeable too that the Trombidiformes are frequently more numerous than in other situations.

APPARENT SPECIFIC GRAVITIES, MOISTURE CONTENTS AND POPULATIONS OF ACARINA AND COLLEMBOLA OCCURRING IN RAW HUMUS IN NATURAL, UNDISTURBED HEATHLAND, LITTER EXCLUDED

Table 36

Depth in inches	Acarina and Collembola		Apparent specific gravity of medium	Moisture Content % of Fresh Volume	Moisture Content % of Fresh Weight
	Numbers	%			
0—$\frac{3}{8}$	460	82.1	0.19	45.4	70.9
$\frac{3}{8}$—$\frac{7}{8}$	65	11.6	0.28	61.0	68.8
$\frac{7}{8}$—$1\frac{3}{8}$	16	2.9	0.45	76.1	62.7
$1\frac{3}{8}$—$1\frac{11}{16}$	13	2.3	0.45	44.2	49.5
$1\frac{11}{16}$—$2\frac{3}{16}$	6	1.1	0.86	51.3	37.4

Note.—These apparent specific gravities are calculated on the basis of extraction-dried weights, and are therefore somewhat higher than the values obtained from oven-dry weights.

*Biomass may be defined as the weight of a species population per unit of area (Allee, 1949), Here it is used in a looser sense and covers volume and weight per unit area or unit volume. depending on data available.

The most important pedological attributes influencing the fauna in raw humus appear to be pore space and water content. Although the pore volume of the raw humus layer is usually in the region of 75 per cent of the total volume (Rennie, unpublished data), much of it is either too small for the fauna or is occupied by water and thus denied to these aerophilous creatures. The apparent specific gravity or volume weight of the raw humus milieu, that is, the ratio between the dry weight of a given volume of undisturbed soil and the weight of an equal volume of water, is a useful indication of pore space available. Table 36 gives these values for the raw humus covering, and it will be seen that the ratios increase as one proceeds down the profile. In ecological studies, moisture contents are usually expressed on a weight basis, but it is obvious that the apparent specific gravity gradient will affect these values, and give a false impression of the water regime (Table 36). Expression of water content on a volume basis (Forsslund, 1944-45) overcomes this difficulty, and indicates that the pore space in part of the raw humus layer is almost completely occupied by water. The larger populations occupying a greater volume of the drier raw humus resulting from cultivation, and also from the presence of trees, is additional evidence that water is an active competitor for living space.

TOTAL ACARINA AND COLLEMBOLA OCCURRING IN RAW HUMUS SAMPLE WITH CLEARLY DEFINED F AND H LAYERS

Table 37

Depth in inches	Numbers per sample			Number per square metre	Apparent specific gravity
	Acarina	Collembola	Total		
Litter about 1	214	12	226	91,900	—
Raw humus 0-2	347	342	689	280,200	0.2
Total	561	354	915	372,100	

Numbers per square metre x 4,000=approximate numbers per acre.

A further interesting feature underlining the importance of pore-space distribution and water content may be mentioned here. Although it is seldom possible to subdivide the raw humus of this particular mor into F and H layers, the largest Collembola population recorded in these investigations (Table 37) was obtained from a sample which had very clearly differentiated F and H layers. It is possible that the small numbers of Collembola normally found may be due to the fact that the size range of individuals in this order does not descend to the level of the smallest Acarina species. Undoubtedly other factors may influence the population structure. For example the occurrence of a species of the Acaridoidea (related to the cheese mites) near the base of the raw humus horizon suggests that lack of oxygen may be a limiting factor.

To sum up, the meiofauna of the natural, undisturbed heathland is composed of large populations with a relatively small number of small species, which are confined to a narrow surface and subsurface zone of the raw humus. There seems reasonable evidence for stating that water content, lack of suitable food material, and perhaps lack of oxygen, form effective barriers to any expansion of the faunistic structure or the appearance of larger species in this biome. These findings are contrary to present theories concerning the conditions existing in mor raw humus.

Much stress has been placed on conditions in the natural, undisturbed heathland, and the factors at play in deciding the kinds and numbers of meiofauna occurring there. In the writer's view, the study of a simple, natural system of this type is an essential preliminary to investigations of artificial processes which render these sites amenable to tree growth. The changes in mor raw humus caused by cultivation, and the possible activating effect of this process have received some attention. Determination of the populations occurring in cultivated profiles offers serious, practical difficulties, and on this account the number of samples examined is small. As already mentioned, there is usually a larger population occupying a greater volume of the raw humus "sandwich" created in the cultivation process. Reduction in water content is probably the main factor responsible for this change in distribution. This effect is noticeable even in recently cultivated profiles (sampled two years after ploughing), and the writer has found numbers of a Ptyctima mite, *Pseudotritia ardua* (Koch), and quite large amounts of mite excrement in the region where the two raw humus layers meet. It is indeed remarkable that this species should be present in quite large numbers in this ploughed profile, and yet be completely absent from the undisturbed sample sites a few hundred yards away. *Pseudotritia ardua* feeds on litter, wood and decaying stems, and the active feeding taking place appeared to be due to the presence of this mite feeding on dead *Calluna* leaves and stems buried in the ploughing process. Although there are obvious practical difficulties in ploughing areas where there is a very strong growth of *Calluna* or other vegetation, it is possible that avoidance of the burning that is sometimes done before ploughing may assist in building up the numbers of a species of this type, and the chain of processes set in motion by feeding of this nature may be of importance in activating raw humus. It is intended to continue this study of the raw humus "sandwich".

Culture experiments have been concerned with an investigation of the biology of certain species of the Oribatoidea to obtain information on food habits, amounts of litter consumed in culture, and litter preferences of litter-feeding species. These studies have shown that some species, especially *Steganacarus magnus* (Nic.) and *Nothrus silvestris* Nic. consume large amounts of litter, but attempts to obtain a quantitative measure of the litter ingested have been inconclusive. Litter preference experiments with *Steganacarus* indicate that this species when cultured on ash, birch, Douglas fir and Scots pine, shows a marked preference for broadleaf as opposed to conifer litter, and ash to birch. It seems that present stress on fungi as a direct source of food for the Oribatoidea is not in accord with the experimental evidence. It is suggested that there may be a possible relationship between palatability of litter species and reputed "rate of decomposition"; and on this account litter-feeding mites may play a part in the more rapid litter decomposition which frequently occurs in mixed broadleaf and conifer stands. The accumulation of conifer needles may provide suitable environmental conditions, whilst the broadleaf litter provides palatable food material for the maintenance of litter-feeding populations of soil Acarina at a high level.

The factors responsible for these preferences are not clearly understood, but there are some pointers which should repay examination. Wittich (1943) has shown that the C/N ratio of the litter is negatively correlated with rate (or type?) of decomposition. Lyford's (1943) feeding experiments with millepedes demonstrated a positive relationship between palatability and calcium content of the litter. Unfortunately he did not determine C/N values, but there is an indication that they are negatively correlated with calcium content. Bearing in mind that calcium is essential for the metabolism of the earthworm, there are indications that the calcium content of the litter source may have an import-

ant influence on the faunal and floral population, and on the composition of the latter will depend the nature of the humus formation.

It is probable that physical properties of the litter also have an important bearing on the breakdown process. In culture experiments the writer has observed that the moisture content of the food material is of great importance, and oribatid mites, for example, do not appear to feed on litter unless it is completely saturated. Kühnelt (1950) further points out that there is very little activity in the autumn in freshly fallen litter until it has become thoroughly moistened; however there is evidence that litter-feeding species will not consume freshly fallen leaves for reasons other than lack of moisture. There is no information concerning the length of time leaves, e.g., xerophytic types, will resist the penetration of water, although there appear to be considerable differences in moisture uptake of litter species when small pieces of leaves and needles are kept in a water-saturated atmosphere for ten days, and this may be one reason why certain litters are unpalatable to the fauna. Further investigations of these attributes in relation to litter-feeding fauna should provide valuable information.

REFERENCES

Allee, W. C., Emerson, A. E., Park, O., Park, T. and Schmidt, K. P. (1949). *Principles of Animal Ecology*. Saunders, Philadelphia. pp. 837.

Drift, J. van der (1950). Analysis of the animal community in a beech forest floor. *Meded. Inst. Toegep. biol. Onderz. Nat.* 9: 1950 (1-168).

Forsslund, K. H. (1944-45). Studier över det lägre djurlivet i nordsvensk skogsmark. [Studies on the soil fauna of North Swedish forest soils.] *Medd. Skogsförsöksanst. Stockh.* 34: 1944-45 (1-283).

Kühnelt, W. (1950). *Bodenbiologie mit besonderer Berücksichtigung der Tierwelt.* [Soil biology with particular reference to the animal kingdom.] Herold, Vienna. pp. 368.

Lyford, W. H. Jr. (1943). The palatability of freshly fallen forest tree leaves to Millipeds. *Ecology* 24: 1943 (252-261).

Murphy, P. W. (1953). The biology of forest soils with special reference to the mesofauna or meiofauna. *J. Soil Sci.* 4: 1953 (155-193).

Salt, G., Hollick, F. S., Raw, F. and Brian, M. V. (1948). The Arthropod population of pasture soil. *J. Anim. Ecol.* 17: 1948 (139-150).

Wittich, W. (1943). Untersuchungen über den Verlauf der Streuzersetzungen auf einem Boden mit Mullzustand II. [Investigations on the disintegration of litter on a mull soil, II.] *Forstarchiv* 19: 1943 (1-18).

THE RELATIONSHIP BETWEEN LARCH CANKER AND TRICHOSCYPHELLA WILLKOMMII

By Dr. J. G. MANNERS

Department of Botany, Southampton University

The taxonomy of the fungus species associated with larch canker having been clarified, work has continued on the physiology of *Trichoscyphella hahniana* and *T. willkommii*, and on the relationships between canker, attack by *T. willkommii* and frost damage. A paper incorporating results obtained up to August 1952 has been accepted for publication in the Transactions of the British Mycological Society.

Fungal Physiology

Both *T. willkommii* and *T. hahniana* can be grown easily on sterile (autoclaved) green larch twigs. A single spore culture of *T. hahniana* will produce apothecia typical of that species under such conditions, but a single spore culture of *T. willkommii* produces only microconidia. This suggests that *T. willkommii* may be heterothallic, and an experiment with a number of paired cultures has been set up. Several months elapse before larch twig cultures produce apothecia, and the results of this experiment are not yet available. Both species grew well, but without producing apothecia, on minced bark from green larch twigs, and rather slowly and poorly on minced bark from dead larch twigs. In both cases the minced bark was made up as an agar medium.

In order to study the nutritive requirements of the two species more closely, cultures were made of each on Dox agar, and on Dox agar with yeast extract, using various carbohydrates as carbon sources. The two species behaved similarly: growth was best on Dox with yeast and starch; good on Dox with yeast and sucrose; moderate to poor on Dox with starch or sucrose, and also on Dox with yeast and cellulose; very poor on Dox with cellulose. On 3 per cent malt agar both species grew well with an optimum growth rate of 10-15 millimetres per week (depending on the isolate) at 20°C. (68°F.). At 5°C. (41°F.) growth is slow (0.5 mm. per week), but definite. Determinations of the growth rate at freezing temperatures are being made.

Inoculation Experiments

Further observations have been made on the trees inoculated at Penzance, mentioned in the writer's previous report. Most of the trees inoculated in 1950 had been removed in 1951, but four, inoculated with *T. willkommii*, which had developed canker, were retained. These cankers were still unhealed on 2nd September, 1952 and die-back had occurred in two of the trees. These results indicate that cankers may persist for at least two years in the absence of frost. Eleven out of twenty trees inoculated with *T. willkommii* on 18th April, 1951 have now become infected. Two cankers noted previously had healed by 2nd September, 1952, but on that date infection was noted on three trees previously considered uninfected, i.e., there had been a delay of 18 months between inoculation and the appearance of an obvious canker. This time-lag may explain some previous negative results reported in infection experiments. The results suggest that trees of Scottish origin (half those inoculated) are rather less susceptible than those of Swiss origin, but this cannot be considered proved until the results of further experiments, now in progress, are available. Early in 1952 the remaining fifty trees at Penzance were inoculated, and preliminary results confirm those obtained previously. As a further trial, twenty trees of each of four origins (two Scottish, one Swiss and one Polish), together with twenty trees of Japanese Larch, were obtained. These were potted and established in frost-proof cold frames, erected for the purpose, at Southampton. They are to be inoculated on 4th May, 1953 with *T. willkommii*. Several strains of the fungus will be used, some old, some freshly isolated, some from European larch and some from Japanese larch, since previous results had suggested that cultures lost their pathogenicity with age, and no inoculations on Japanese larch have previously been made.

Freezing Experiments

The object of these experiments is to obtain cankers, or at any rate, local bark injury, by freezing, and then determine whether further freezing, the fungus *T. willkommii*, or both, are required to maintain open cankers. Experience showed that when small trees were subjected to frost in a refrigerator,

die-back rather than canker resulted, so local freezing of areas of bark was resorted to. Solid carbon dioxide is an effective freezing agent, but when applied direct to the bark, is uncontrollable. An apparatus has been designed which blows a current of cold air at a known and controllable temperature on to small areas of the trunks of three to four-year-old potted trees. The temperature of the bark surface is measured electrically with the aid of a "thermistor". The considerable technical difficulties involved, resulting from the low thermal capacity of air, have now been almost overcome, and a sufficient stock of potted trees is now available to enable experiments to begin in the very near future.

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

By J. A. TOWNROW
Botany School, University of Cambridge

The Sooty Bark disease of sycamore and *Cryptostroma corticale* (Ell. & Ever.) Gregory & Waller, the presumed causative agent, have been described by Gregory and Waller (*Trans. Brit. Myc. Soc.* 34, 1952) and also by Moreau who worked upon material from Paris and neighbourhood (*Bull. Mycol. Soc. France* 1951).

The work mentioned here has been based upon these descriptions and has been directed towards discovering the mode of entry of *C. corticale* into the tree, with associated external factors influencing entry, and the spread of the fungus in a diseased tree, and also any ecological factors influencing ease of infection, such as the presence of other organisms which might weaken a tree and pre-dispose it to attack.

One important requirement was a source of spores produced under known, and if possible, sterile conditions. This has been made possible by using a method kindly communicated by Mr. J. G. Savory of the Forest Products Research Laboratory, Princes Risborough, involving the insertion of surface sterilized sycamore twigs into a culture on agar of *C. corticale*. By this means a plentiful source of spores produced in the laboratory has been available.

These spores have been used in the experiments described below. One set of experiments have been planned to elucidate the relation between relative humidity and vapour pressure and the spore germination. The results suggest the requirement of the spores are exacting, for in the absence of nutrient (here in the form of 3 per cent malt agar) 50 per cent germination is obtained after three days at 20°C. and at 100 per cent relative humidity. However in the presence of nutrient the germinating period is only 24 hours.

Temperature has been found to influence *C. corticale* markedly. Mycelial growth falls at 10°C. (50°F.) to a third its value at 25°C. (77°F.), and similarly spore germination and elongation of the germ tubes fall noticeably; at 5°C. (41°F.) after 7 days no germination was seen.

In another set of experiments, based upon the investigation by F. T. Brooks and Moore (*Trans. Camb. Philos. Soc.* 1, 1922) on spore germination in *Stereum purpureum*, shoots were decapitated, or fresh cut twigs placed in water, and spores applied to the cut ends. Since there was no significant difference between the living shoots or the cut twigs the results will be taken together. The findings may be summarised as follows:

(1) The spores are not drawn down into the vessels, whether the spores be applied in a suspension, or dry, or immediately upon cutting the shoot, or after a time interval.

Germination takes place on the cut surface, and germ-tubes grow down into the twig. This behaviour implies that *C. corticale* may be more susceptible to changes in the external environment than *Stereum purpureum*, for example, where the spores are drawn a few millimetres into the vessels, and so protected to some extent from extremes of drying or heat.

(2) The germ tubes and subsequent mycelium grow much more readily in the non-lignified and storage tissues, i.e. cortex, phloem, wood rays, wood parenchyma and pith, than in the vessels and tracheids, where the hyphae are long, narrow and unbranched. The cell walls in the xylem are penetrated by a very fine hypha, and there is no sign of erosion of any lignified tissue.

(3) The effect of temperature upon spore germination and penetration by the germ tubes is very marked; for both are vigorous at 25°C. (77°F.), but practically non-existent at 10°C. (50°F.) after 9 days.

(4) Germination and penetration are rapid upon a fresh wound, suggesting that the presence of a layer of liquids enables the spores to germinate even if the atmosphere is at less than the minimum humidity, but under experimental conditions, infection of dry wounds (3-10 days old) was unobtainable. If the wound was moist, some penetration took place.

Inoculation experiments are in progress to try and determine the time of year and possibly the mode in which the fungus enters the tree. Saplings have been inoculated at bi-monthly intervals, and the wounds covered in a variety of ways, to obtain various degrees of aeration. Other trees have been wounded, e.g. by removing the bark or both the bark and phloem, and also inoculated at intervals. In this case the wounds are covered by metal-foil only. So far no results are to hand, but Dr. P. H. Gregory found (private communication) that up to eleven months must elapse after inoculation before lesions appear; and Mr. N. F. Robertson reports one successful inoculation out of six made in April 1952 and recorded in October of that year.

Observations have also been made on naturally infected trees to try to follow the progress of *C. corticale* in a tree after infection, and to see if any other organisms are constantly associated with the disease. These experiments are far from complete, and the results here given are purely tentative. A further point is that absence of any organism when attempting to isolate it from diseased material does not constitute proof of its absence in the original material.

A stain has been described by both Gregory and Waller and by Moreau. This stain is associated with wounds from which some twenty different organisms have been isolated. It has also been seen where no organism could be found. However it is regularly present in the case of infection by *Cryptostroma*. The stain fades after death of the tree but may still be recognisable two years after death. *Cryptostroma* is present in the stained wood, but usually mixed with other organisms, of which *Trichoderma viride* and *Fusarium* spp. are common; whereas for about 2 inches outside the stain, in the clean wood, *C. corticale* can be isolated pure.

C. corticale, if present in the main stem, rather rarely grows into side branches while they are still alive, though they die if the main stem dies; but the reverse movement from a side branch to a stem seems more common. Further the fungus (and stain) can be traced into the root system, and *C. corticale* has been isolated from roots as small as 1.5 mm. in diameter: however if a root dies it is rapidly colonised by saprophytes which tend to spread into the main

root, so isolating *C. corticale*, in areas of apparently living tissue. *Armillaria mellea* has very frequently been found on the roots of diseased trees, in one case where *C. corticale* was present in the central region of the root; but usually where *A. mellea* is present *Cryptostroma* is absent.

Observations seem rather to suggest *Cryptostroma* spreads down into the root from the aerial portions of the tree, failing to colonise the roots if they have died before it reaches the butt, in which case other fungi, e.g. *Armillaria mellea* and *Trichoderma viride* occupy the roots.

MEGASTIGMUS SEEDFLIES INFESTING CONIFER SEED

By N. W. HUSSEY

Department of Forest Zoology, University of Edinburgh

Amblymerus apicalis, the most important parasite of *M. spermotrophus*, has been reared from *M. pinus* in cones of *Abies nobilis* at Blackhall, Aberdeenshire.

Dissections of female *Amblymerus* showed that they are capable of laying about forty eggs, which is about the upper limit of *Megastigmus* fecundity as observed in the field. These females emerge during the late summer and remain on the wing for a considerable time. Laboratory tests suggest that they live at least three months. In common with many Pteromalids they are incapable of laying fertile eggs until they have eaten protein material from the host larvae. As their ovipositors are short they can only reach the *Megastigmus* larvae when the cones open and allow them access to the seed. Having imbibed protein they develop ripe, fertile eggs within three to six days. Field observations showed that *Amblymerus* will only search for seed remaining within the cones, and when seed has been shed to the forest floor no further parasitization takes place. Furthermore the searching female is only attracted to the host habitat when on the branches of the trees; cones blown to the ground are not investigated. Normally the gradual opening of the cones allows sufficient time for the parasites to secure protein and hence produce viable eggs before the seed begins to fall. Under conditions of very low humidity in the autumn, however, seed-fall may progress so rapidly as to reduce parasitization.

Among the conclusions to be drawn from the field studies are the following:—

(1) The number of eggs laid by both *Megastigmus* and its parasite *Amblymerus* is markedly influenced by the density of the females.

(2) The fecundity of the parasite is below that of the host under similar density conditions.

(3) The capacity for searching is almost equal in both host and parasite. As they are both searching for the same host-habitat this suggests that *Amblymerus* should be an efficient controlling agent.

(4) In poor seed-years parasitism by Amblymerus may reach high levels (80 per cent) but the average level is from 40 to 50 per cent.

(5) The percentage of infection by *Megastigmus* is least in good seed-years following a series of poor crops, but the occurrence of an early or late spring, causing a lack of synchronisation between the flight period of the females and the suitability of the cones for attack, may produce a low infestation even in a poor seed year. The fact that pollination, oviposition by *Megastigmus*, and fertilization of the seed, occur at different times means that unfavourable

weather at any one of these periods can produce unexpected levels of *Megastigmus* damage.

(6) Eating of the seed by mice results in the destruction of a large number of larvae, but it has been estimated that where *Amblymerus* is present the long-term effect of increased rodent attack is to increase the density of *Megastigmus* and reduce that of the parasite.

(7) Where both parasite and host occur, the level of *Megastigmus* infection is lower than elsewhere. It would be useful to extend the activity of this parasite by introducing cones from within its range to other forests. Care would have to be taken to prevent the escape of adult *Megastigmus* by keeping the cones within a closed vessel until their flight period is over.

(8) As the cones are susceptible to oviposition by *Megastigmus* for only two or three weeks, depending upon the phenology of the crop, spraying of seed-orchards or especially valuable seed stands becomes a possibility. Such spraying should take the form of residual sprays directed at the adults as they emerge from any seed lying on the forest floor.

(9) The problem of extended diapause in *Megastigmus* has been investigated in many laboratory experiments and it is concluded that a small proportion (10 per cent) of the population have the tendency genetically fixed. A further proportion enter prolonged diapause if spring temperatures are low. Prolonged diapause affects a higher proportion of the population in North Scotland than in Southern England. Contrary to the impression gained in the field that humidity influenced diapause (1951 Report), laboratory tests showed that this factor had no influence on the percentage remaining in diapause for a second year.

This study has now been concluded and the results are being summarised in the form of a thesis.

STUDIES OF VARIATION IN CONIFERS

By Dr. E. V. LAING
Department of Forestry, University of Aberdeen

During the period 1952-53 research has been continued along the usual lines.

Larch

The investigation into the cone and seed variation in European larch was continued, and considerable progress made in writing a report, with a view to publication.

The task of identifying newly germinated Japanese, European and hybrid larches has been somewhat complicated by the finding that, although Japanese larch seedlings are very constant in their cotyledon anatomy, European larch shows considerable variation. It is hoped that by the examination of further samples, the cotyledon differences will indicate definite strains. All the European larches so far show a thicker epidermis and more sclerenchyma formation than Japanese larch, whilst the general plan of the fibrovascular bundle is different.

Considerable work remains to be done on the morphological variation in Japanese larch in order to arrive at the true systematy of this species.

Douglas Fir

Further work has been done in connection with variation in this species as

found in Britain. It is evident that there are several distinct morphological strains as defined by:

(*a*) Colour of male and female flowers.
(*b*) Size of cone and length of bracts.
(*c*) Development of hypodermis.
(*d*) Production of stone cells in the mesophyll of the leaf.
(*e*) Hairiness of the shoot.

Stone cells in the leaf are associated with *Pseudotsuga glauca* (blue Douglas) and with the Japanese Douglas firs. Many so-called green Douglas firs, however, show this interesting feature, together with other characters associated with the blue Douglas. They often show a darker brush-like foliage and altogether might be regarded as intermediate between the green and the blue Douglas firs.

In the seed bed these trees are markedly different from the true green Douglas fir in respect of the terminal bud. In the Oregon Douglas fir the terminal bud is covered over by the terminal leaves, whereas in the other the bud is exposed. Further controlled tests are required to prove this definitely.

This tree with stone cells and brush-like foliage is taken to be a very definite strain, often of very good quality. There are, however, on either side of this, trees showing only one or other of these characters together with differences in leaf.

Pinus contorta

It is indicated that there are two main trees in our *Pinus contorta* plantations and their differences may be tabulated as shown in Table 38.

DIFFERENCES BETWEEN TWO TYPES OF PINUS CONTORTA

Table 38

	"PINUS MURRAYANA"	"PINUS CONTORTA"
Bud	Small	Large
Leaves	Yellowish green, broader	Green and narrow
Bark	Thin scales as tree becomes older—$\frac{1}{4}$ in.	Thicker and more corky $\frac{3}{4}$—1 inch
Cones	Larger	Smaller, often mamillate at base
Seed:		
(*a*) length	3.5—5 mm.	2.5—4 mm.
(*b*) colour	Reddish or greyish	Black or bluish black
(*c*) surface	Ridged beneath	Rough
Seedling:		
(*a*) No. of cotyledons	4—6	3—5
(*b*) length of cotyledons	20—30 mm.	15—18 mm.
(*c*) primary leaves	Broad and very pointed fewer short teeth	More blunt, Numerous teeth
Timber:		
Summer Wood	Thinner and more open	Denser
Med. Rays	Broader, heterogeneous	Narrower, homogeneous
Ray pits	Small	Large

Printed in Great Britain under the authority of Her Majesty's Stationery Office
by Joseph Wones Ltd., West Bromwich

(2027) Wt. 4569/2018 K.20 2,500 4/54 J.W.Ltd. Gp. 517

SELECTED
FORESTRY COMMISSION PUBLICATIONS

FOREST RECORDS

No. 2. THE RAISING OF ASPEN FROM SEED. (70-576-2.) 1*s.* 0*d.* (1*s.* 1½*d.*)

No. 3. CENSUS OF WOODLANDS, 1947-49. Summary Report. (70-576-3.) 9*d.* (10½*d.*)

No. 4. CAMBIAL INJURIES IN A PRUNED STAND OF NORWAY SPRUCE (70-576-4.) 1*s.* 3*d.* (1*s.* 4½*d.*)

No. 5. GENERAL VOLUME TABLE FOR OAK IN GREAT BRITAIN. (70-576-5.) 4*d.* (5½*d.*)

No. 6. GENERAL VOLUME TABLE FOR BEECH IN GREAT BRITAIN. (70-576-6.) 4*d.* (5½*d.*)

No. 7. GENERAL VOLUME TABLE FOR BIRCH IN GREAT BRITAIN. (70-9999.) 3*d.* (4½*d.*)

No. 8. GENERAL VOLUME TABLE FOR SCOTS PINE IN GREAT BRITAIN. (70-576-8.) 1*s.* 6*d.* (1*s.* 7½*d.*)

No. 9. GENERAL VOLUME TABLES FOR EUROPEAN LARCH IN GREAT BRITAIN. (70-576-9.) 1*s.* 6*d.* (1*s.* 7½*d.*)

No. 10. GENERAL VOLUME TABLES FOR NORWAY SPRUCE IN GREAT BRITAIN. (70-576-10.) 1*s.* 0*d.* (1*s.* 1½*d.*)

No. 11. GENERAL VOLUME TABLE FOR CORSICAN PINE IN GREAT BRITAIN. (71-576-11.) 1*s.* 6*d.* (1*s.* 7½*d.*)

No. 12. GIRDLING OR BANDING AS A MEANS OF INCREASING CONE PRODUCTION IN PINE PLANTATIONS. (71-576-12.) 6*d.* (7½*d.*)

No. 13. CHEMICAL CONTROL OF WEEDS IN FOREST NURSERY SEEDBEDS. (71-576-13.) 2*s.* 0*d.* (2*s.* 1½*d.*)

No. 14. GENERAL VOLUME TABLES FOR JAPANESE LARCH IN GREAT BRITAIN. (71-576-14.) 9*d.* (10½*d.*)

No. 15. GENERAL VOLUME TABLES FOR DOUGLAS FIR IN GREAT BRITAIN. (71-576-15.) 1*s.* 6*d.* (1*s.* 7½*d.*)

No. 16. EFFECTS OF PARTIAL SOIL STERILIZATION WITH FORMALIN ON THE RAISING OF SITKA SPRUCE AND OTHER CONIFER SEEDLINGS. (71-12-16.) 1*s.* 6*d.* (1*s.* 7½*d.*)

No. 17. ADELGES ATTACKING JAPANESE AND HYBRID LARCHES. (71-12-17.) 1*s.* 3*d.* (1*s.* 4½*d.*)

No. 18. THE USE OF LARGE DIAMETER WHEELS ON FOREST EXTRACTION VEHICLES. (71-12-18.) 9*d.* (10½*d.*)

No. 19. THE MANUFACTURE OF WOOD CHARCOAL IN GREAT BRITAIN. (71-12-19.) 1*s.* 3*d.* (1*s.* 4½*d.*)

No. 20. THE USE OF CHUTES FOR EXTRACTION OF THINNINGS. (71-12-20.) 6*d.* (7½*d.*)

No. 21. USE AND MANUFACTURE OF WOOD FLOUR. (71-12-21.) 6*d.* (7½*d.*)

No. 22. SHELTERBELTS FOR WELSH HILL FARMS. (71-12-22.) 2*s.* 0*d.* (2*s.* 1½*d.*)

No. 23. FIRES IN STATE FORESTS IN THE YEARS 1929-1952. (71-12-23.) 1*s.* 6*d.* (1*s.* 7½*d.*)

No. 24. REVISED YIELD TABLES FOR CONIFERS IN GREAT BRITAIN. (71-12-24.) 1*s.* 3*d.* (1*s.* 4½*d.*)

No. 25. JAPANESE LARCHES AT DUNKELD, PERTHSHIRE. (71-12-25.) 2*s.* 0*d.* (2*s.* 1½*d.*)

No. 26. DROUGHT CRACK OF CONIFERS (71-12-26) 2*s.* 6*d.* (2*s.* 7½*d.*)

No. 27. USE OF HOME-GROWN TIMBER IN WOOD TURNING AND RELATED TRADES IN SCOTLAND IN 1953 (71-12-27). 1*s.* 3*d.* (1*s.* 4½*d.*)

No. 28. VOLUME TABLE FOR SMALL HARDWOOD TREES (71-12-28). 9*d.* (10½*d.*)

(continued overleaf)

SELECTED
FORESTRY COMMISSION PUBLICATIONS

REPORTS ON CENSUS OF WOODLANDS

No. 1. WOODS OF FIVE ACRES AND OVER. 1947-1949. (71-11-1*) 12*s.* 6*d.* (12*s.* 10*d.*)

No. 2. HEDGEROW AND PARK TIMBER AND WOODS UNDER FIVE ACRES, 1951. (71-11-2*). 5*s.* 0*d.* (5*s.* 2*d.*)

No. 3. WELSH COUNTY DETAILS. 1947-1949. (71-11-3). 4*s.* 0*d.* (4*s.* 3*d.*)

No. 4. SCOTTISH COUNTY DETAILS. 1947-1949. (71-11-4*). 10*s.* 0*d.* (10*s.* 4*d.*)

No. 5. ENGLISH COUNTY DETAILS. 1947-1949. (71-11-5*). 12*s.* 6*d.* (13*s.* 0*d.*)

REPORTS ON FOREST RESEARCH

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1949. (70-620-0-49.) 1*s.* 9*d.* (1*s.* 11*d.*)

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1950. (71-2-0-50.) 3*s.* 6*d.* (3*s.* 9*d.*)

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1951. (71-2-0-51.) 4*s.* 6*d.* (4*s.* 9*d.*)

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1952. (71-2-0-52.) 4*s.* 6*d.* (4*s.* 9*d.*)

ANNUAL REPORT FOR THE YEAR ENDED 30TH SEPTEMBER, 1953. (H.C. 174, Session 1953-54.) 3*s.* 0*d.* (3*s.* 2*d.*)

BULLETINS

No. 13. STUDIES ON TREE ROOTS. AUGUST, 1932. (70-31-13.) 3*s.* 6*d.* (3*s.* 8*d.*)

No. 14. FORESTRY PRACTICE—A summary of methods of Establishing Forest Nurseries and Plantations with advice on other forestry questions for Owners, Agents and Foresters. February, 1933. 5th Edition, 1951. (70-31-15-51.) 3*s.* 0*d.* (3*s.* 2*d.*)

No. 15. STUDIES OF CERTAIN SCOTTISH MOORLANDS IN RELATION TO TREE GROWTH. MAY, 1933. (Revised 1947.) (70-31-15-47.) 2*s.* 6*d.* (2*s.* 8*d.*)

No. 16. STUDIES ON THE PINE SHOOT MOTH, JULY, 1936. (70-31-16.) 1*s.* 9*d.* (1*s.* 10½*d.*)

No. 17. THE CULTIVATION OF THE CRICKET BAT WILLOW, JULY, 1936. (70-31-17.) 2*s.* 0*d.* (2*s.* 2*d.*)

No. 18. SPRING FROSTS, WITH SPECIAL REFERENCE TO THE FROSTS OF MAY, 1935. JULY, 1937. 2nd Edition, January, 1946. (71-5-18.) 4*s.* 6*d.* (4*s.* 9*d.*)

No. 19. POPLARS. (71-5-19*) 7*s.* 6*d.* (7*s.* 8*d.*)

No. 20. STUDIES ON BRITISH BEECHWOODS. (71-5-20*.) 12*s.* 6*d.* (12*s.* 9*d.*)

No. 22. EXPERIMENTS IN TREE PLANTING ON PEAT (71-5-22*). 10*s.* (10*s.* 3*d.*)

Prices in brackets include postage

Obtainable from H.M. Stationery Office or through any bookseller.

A complete list of publications (Sectional List No. 31) is obtainable on request, from H.M. Stationery Office, or from the Secretary, Forestry Commission, 25 Savile Row, London, W.1.

S.O. Code No. 71-2-0-53