FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1952

LONDON: HER MAJESTY'S STATIONERY OFFICE
1953

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INTRODUCTION

By JAMES MACDONALD
Director of Research and Education

During the year under review, forest research in Great Britain suffered a severe loss in the death of Professor F. T. Brooks which took place in January, 1952. As a member of the Advisory Committee on Forest Research, to which he was appointed in 1935, Professor Brooks exercised a strong influence, and his long experience and wide knowledge were of great value, particularly in the expansion which followed the war. In the last few years, as Chairman of the sub-committee on Nursery Nutrition, he was largely responsible for the initiation and maintenance of an important series of researches which has thrown much light on the complex problem of the nutrition of forest trees.

Professor H. M. Steven of the University of Aberdeen has taken Professor Brooks's place as Chairman of the Nursery Nutrition sub-committee.

Mr. J. A. B. Macdonald, who, for many years has been in charge of silvicultural work in Scotland, has left the Research Branch on promotion to the rank of Conservator. Mr. Macdonald's departure is a severe loss for he has an intimate knowledge of many sides of silviculture based on a long and varied experience in the field. The retirement, on age-limit, of Mr. H. S. Hanson, entomologist, has also deprived us of the services of an experienced and highly-skilled officer.

This report includes a note of the work carried out on utilisation by the recently formed section which is dealing with these investigations. Attention has been paid to hazel coppice, in a survey of which the Rural Industries Bureau are co-operating, while surveys have been made of the charcoal industry and one or two minor wood-using industries. Close contact has been kept with the Forest Products Research Laboratory and arrangements have been made for the supply to the Laboratory of various home-grown coniferous timbers for testing.

The reports by the Commission's research officers follow the usual lines, but they include notes on the use of broom as a nurse for conifers at Wareham in Dorset and on the use of poisons to kill standing trees in order to facilitate the subsequent removal of the bark.

Among the reports from outside workers, there is a summary of the work on the old Scots pine stands in Scotland by Mr. A. Carlisle of the University of Aberdeen, and a short account by Dr. J. G. Manners of Southampton of his work with larch canker. The other reports from research workers outside the Commission relate to researches which have been mentioned on previous occasions.

The Advisory Committee on Forest Research held two meetings during the year. On the first occasion, it met at Scarborough on the 29th and 30th September, 1951, and on the second, on 20th March, 1952, it met in London. The meetings discussed the report for the previous year and the programme of work for the current twelve months. While at Scarborough, the Committee were able to inspect the experimental areas in Allerston Forest, and they had the opportunity of discussing with Professor Champion's team of soil workers

from Oxford University the series of researches which have been undertaken in that district.

The sub-committee on Nursery Nutrition held a meeting in the New Forest on 9th and 10th October, 1951, when the programme of work was examined. Visits were paid to experiments at Ringwood and Wareham. The impressive series of experiments which has been designed by this sub-committee has meant much work for Dr. E. M. Crowther and Dr. A. B. Stewart and their staffs, to whom we are greatly indebted. Thanks are also due to the Directors of Rothamsted and of the Macaulay Institute for Soil Research for the facilities which they have placed at the disposal of the sub-committee.

As in former years, close contacts have been maintained with Universities and other institutions in this country, while the increased number of visitors from overseas is a measure of the greater interest which is being aroused in other countries in forest research in Great Britain.

The Forestry Commission continues to take part in the work of the International Union of Forest Research Organisations and the Director of Research attended the meeting of its Permanent Committee in Holland in September, 1951.

Mr. R. F. Wood, silviculturist in charge of experimental work in the southern half of Great Britain, has been awarded a Nuffield Foundation Fellowship under which he will study the forest trees of the Pacific coast of Canada.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE
Chief Research Officer

Staff and Accommodation

Mr. J. A. B. Macdonald, Silviculturist North, was transferred in November, 1951, to the Directorate for Scotland, on promotion to Conservator, South Scotland. His place was taken by Mr. M. V. Edwards. Mr. H. S. Hanson, Forest Entomologist, retired at the end of 1951. Dr. Myles Crooke was appointed as his successor. Mr. C. W. Yeatman worked as a temporary District Officer from November, 1951, to March, 1952, on a special investigation on the rooting of Japanese larch under different types of ploughing at Allerston Forest in Yorkshire. Mr. L. Reynolds was appointed Assistant Utilisation Development Officer and took up duty on 1st January, 1952.

The laboratories at the Forest Research Station, Alice Holt are getting increasingly cramped for space, and the need for an extension is becoming urgent.

Visitors

During the year official visitors to the station totalled 274, and included people from: Australia, Austria, Belgium, Canada, Denmark, Eire, France, Germany, Holland, India, Italy, Lebanon, New Zealand, Norway, S. Africa, Southern Rhodesia, Switzerland, Turkey, Uganda, and W. Africa. Included in the number of visitors were the members of the International Poplar Commission who visited the Research Station on 26th April, 1951, members of the Southern Division of the Royal Forestry Society of England and Wales who came in July, and of the Society of Foresters of Great Britain in September.

The Society of Irish Foresters, several regional branches of the Royal Scottish Forestry Society, and the forestry students of the University of Wales, Bangor, and of Aberdeen University paid visits to experiments. Tours of experimental work were arranged for visiting forest officers from Norway and Pakistan. In the north, tours by groups of District Officers to the main peatland and heathland experimental centres were arranged to bring home to them the latest results of experimental work.

The Season

Two extremely severe gales reaching 80 to 100 miles per hour occurred in January, 1952. In the northern part of Scotland extensive windfalls occurred, and in Caithness and Orkney wind damage was of unprecedented severity. Few of the existing plantations in the extreme north of Scotland escaped unharmed.

After a fairly severe winter, the spring was mild and dry in the north, though in the south the early spring was wet and nursery sowings were inevitably late. Late frosts were noticeably absent.

The Year's Work

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

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

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

Forest Tree Seed Investigations

In November, 1951, Alice Holt Research Station was licensed as a "Private Seed Testing Station", under the Seeds Act, 1920, and since then all routine testing of tree seeds used by the Forestry Commission has been taken over. About 600 seed purity and germination tests were done between November and March.

Examination of cone samples to ascertain the quantity and quality of seed in them was continued, 110 samples being reported on this year. This service is found to be useful as it saves the collection of cones that contain too little good seed to be worth having. Studies in the control of conditions in seed extraction kilns and in seed sampling methods have been commenced. Further confirmatory work on the use of tetrazolium bromide for testing seed viability was done. This method is now adopted as a regular routine for supplementing the standard tests on Copenhagen tanks. A mycological study of the fungi developing on seeds during germination, to determine what species are harmful has been initiated. Seed storage tests continued. It was found that low temperature storage of oak and beech was lethal. Beech seed stratified in an unsealed container, and kept at 25°F., showed 50% germination after 18 months. (Page 12).

Experimental Work in Nurseries

PARTIAL STERILISATION OF THE SOIL

The restoration of fertility by partial sterilisation of the soil was further investigated. Soil steaming experiments were confined to investigating the best and cheapest techniques for steaming, the use of a hood being found most practicable, steam being passed until the soil reaches 180°F., at six inches depth. Attempts at improving the efficiency of partial sterilisation with formalin by sealing the soil in various ways gave inconclusive results. It was found, however, that the amount of water used to dilute a given amount of formalin was important, and that less than 1 gallon of water per square yard (containing 0.10 gallons of commercial formalin) resulted in a smaller growth response by the seedlings. "D-D" soil fumigant was again found very much less effective than formalin. (Page 15).

SOIL ACIDIFICATION

Soil acidification at Widehaugh nursery, in Northumberland, carried out in 1950 by various methods, had no residual effect on the height growth of seedlings from 1951 sowings. (Page 17).

MANURING

Fertiliser experiments in old-established nurseries, including placement of phosphate and potash fertilisers below seed drills, and tests of different forms of nitrogen, gave results confirming previous years' trials, namely that placement gives a limited improvement in seedling growth, while of the various forms of nitrogen fertilisers tried, "flash" (plastic waste), and formalised casein, gave the best results. Trials were carried out with various straw and sawdust composts using ammonium sulphate, formalised casein and spent hops as sources of nitrogen to activate the breakdown of the organic matter. On heathland and woodland soils all composts gave improved growth of seedlings, though how much of this is due to the nitrogenous activators is not clear. Responses on older

established nursery soils were too small to be worth noticing. In some mulching experiments on heathland soil, comparing a bracken mulch with an inert cellulose mulch, the former gave an increase in growth, while the latter slightly depressed it, suggesting that the main effect of a bracken mulch is due to the nutrients leached from it. A long-term fertility demonstration at Teindland heathland nursery in Morayshire, in which regimes of compost and fertiliser applications, separately and in combination, are compared with unmanured controls, was cropped for the second year, and showed best results from fertilisers without compost. A similar demonstration, with the added factors of partial sterilisation and greencropping, has been started at Newton Nursery near Elgin, an old established nursery on agricultural soil. Here formalin treatment had the greatest single effect; fertilisers produced considerable benefit while neither greencrop nor compost treatments have so far had any effect on mean heights as compared with the untreated controls. (Page 18).

GRASS LEYS AND GREEN CROPS

An old greencropping experiment at Kennington nursery near Oxford showed no improvement in fertility on plots that had been under grass ley for several years, as compared with those continuously cropped with Sitka spruce. Plots which had lain fallow continuously did however show significantly greater total production of Sitka spruce seedlings. At Wareham (Dorset) heathland nursery, incorporation of greencrops had a depressing effect on seedling growth in the subsequent year. (Page 22).

SEEDBED WATERING AND IRRIGATION

Nursery irrigation by overhead spray line at Kennington Nursery, to make up deficit of rainfall whenever it reached 0.5 inches below normal, increased Sitka spruce seedling production from 49,000 per lb. of seed for the controls to 89,000 for the irrigated plots. The seedling mean heights were at the same time increased from 1.77 in. to 2.26 in. The number of usable first year seedlings was doubled. Increases in seedling production were not quite so great for Corsican pine and Japanese larch, while Douglas fir showed no response at all. (Page 22).

CHEMICAL CONTROL OF WEEDS IN FOREST NURSERIES

Chemical control of weeds in conifer seedbeds by means of mineral oils applied as a pre-emergent spray was carried out on a user-trial scale in seven nurseries with excellent results. Post-emergent applications gave variable results, sometimes causing damage to the seedlings. Further investigations in post-emergent application are required to elucidate the causes of damage and the conditions under which such treatments can be safely applied. In transplant lines, the best results were obtained by using a hooded spray which confined the chemical to the soil surface and bases of the rows of plants. (Page 24).

MISCELLANEOUS

Intensive culture of Sitka spruce seedlings in frames with soil heating and specially compounded soils resulted in large sturdy seedlings 98 to 100% usable in the first year. The economics of such intensive methods have not yet been worked out. Root pruning of seedlings is being tried to see if good planting stock can be obtained without transplanting. Some experiments with a growth-inhibiting substance are being carried out as a means of saving stock that would otherwise become over-grown and have to be destroyed. Machines are being developed for seed sowing, fertiliser application, formalin application, weed-killer spraying and root pruning. (Page 26).

Work on Problems of Afforestation in Scotland and Northern England

Once again the major effort has been on the provision of trial plantations on poor land hitherto classed as unplantable. In addition, the establishment of species and mixture plots, using modern techniques, has continued on a considerable scale. A large scale experiment on methods of ploughing on heathlands has been planted.

Work on phosphate manuring also continues, while prelminary tests are being made with liming on heathlands. Progress with other projects is briefly described, including an experimental shelterbelt recently planted in Caithness. (Page 28).

Broom and Pine Nursing Experiments at Wareham Forest

Broom has a remarkable nursing effect on Sitka spruce, Norway spruce, *Tsuga heterophylla* and Douglas fir, when planted on these difficult *Calluna* heaths. The control plots are all in severe check, while those nursed by successfully established broom are from two-and-a-half to four-and-a-half times as tall, and are growing vigorously. Addition of phosphate produced a moderate response. The pine nurses included in these trials have not, so far, had any effect. (Page 31).

Investigations into the Rehabilitation of Derelict Woodlands

At Weston Common, Alton Forest, Hampshire, initial treatment of the area is now virtually complete and sales of produce have exceeded expenditure by about £23 per acre. A good deal of tending has, however, still to be done, which may use up this surplus. (Page 33).

At Gardiner Forest in Dorset, where different methods of converting hazel coppice into beech high forest are being compared in a replicated experiment, tending was continued and costed, and assessments of growth and survival made. Casualties were few and no appreciable differences in growth have manifested themselves so far. The treatments under comparison are group planting, with small and large groups cleared in the hazel coppice, strip planting, thinning and under-planting, and complete clearance with planting in the open. The degrees of shade vary from 48% of full light under thinned-out coppice to 100% in the clear-felled area, and in all cases the amount of light is at present sufficient to permit vigorous growth of the beech.

At Well Covert, Haldon Forest, Devonshire, in a type of woodland containing a fair quantity of regeneration of useful species, an experiment has been started to see how much or how little work need be done, and to what extent we can rely on existing regeneration. In view of the enormous size of the problem in Britain as a whole it is important to find out how far we can safely go in the matter of leaving things to nature with a minimum amount of tending and planting, so as to be able to deal with larger areas with the limited labour available. Different methods of rabbit control in dense scrub are also being compared.

Provenance Studies

A fairly comprehensive account is given of the International Larch Provenance Experiments initiated at the instance of the International Union of Forest Research Organisations, in which forty-four different seed lots were raised and planted out in 1946 in five centres in England and in 1947 in one site in Scotland. (At only one centre was the complete set of origins planted). While it is too early to be able to forecast later development, measurements at the age of five years indicated that the lots showing the greatest early vigour came from Moravia and Upper Silesia, and were ahead of strains that had been

established in this country for one or more generations. The least suitable origins, showing high casualties and poor growth, came mainly from the Italian and Swiss Alps. In general, strains from higher elevations grew more slowly than those from lower elevations, though there were individual exceptions to this, notably a strain from Lamerau in the Austrian Alps from an elevation of 2,300 feet. Phenological observations of date of flushing in the spring indicated that some races flushed consistently early and others consistently later in the two years when observations were recorded. (Page 43).

Japanese larch provenance trials have so far shown no consistent variations between provenances, though there are great differences between individual trees within provenance as regards vigour and form.

In Scots pine, trials of Norwegian coastal provenances have been laid down to try and find a strain that will grow better and prove more resistant to wind blast than our local strains, when planted in West Coastal districts in Scotland. A report on some older Scots pine provenance experiments is given, which confirms the superiority of our indigenous origins over imported ones. Finnish races, and races from Georgia and Spain, were particularly poor.

Brief notes are also included on some *Pinus contorta* provenance trials dating from 1934, and some new trials of Corsican pine and Douglas fir provenances.

Forest Ecology

GROWTH OF BEECH IN BRITAIN

Studies of the growth of beech in Britain indicated that, in general, growth in young plantations was faster than that on the Continent, where most young crops originated from natural regeneration. Growth was good on a wide range of soils, including some clay soils, though data from clay areas were very meagre. Shallow chalk soils, or clayey soils with impeded drainage, gave poor growth. Forking in beech appears to be nearly always associated with damage by certain insects to the leading shoot during the period of "Lammas growth". (Page 58).

INFLUENCE OF SHADE ON INCREMENT, STEM FORM AND HEALTH OF BEECH PLANTS IN THE NURSERY

A controlled experiment on the effect of different degrees of shade on young beech plants in the nursery indicated that reduced light has a profound influence on form, and always results in a reduction in dry weight increase of shoot and root. 50% light did not appreciably reduce the amount of Lammas growth and forking, but heavier shading (18%, and about 4%, of full light) conspicuously reduced forking, but also caused deviation of the axis from the vertical so that plants were in danger of assuming a "table-topped" habit. There may be some intermediate degree of shading where improved form may be secured without too serious a loss of vigour. (Page 60).

Forest Genetics

The principal work during the year was the survey of seed stands in the East Conservancy of Scotland, which took five months to complete. The central register of seed stands has been increased by over 220 stands totalling 2,246 acres. The greater proportion of these consisted of seed sources for Scots pine and European larch. (Page 63).

The survey of one Conservancy is to be completed each year and preparations for the work in the North of Scotland are well in hand. The selection of "PLUS" trees for breeding purposes continued, and a "tree bank" or central collection of grafts and cuttings from the selected parents has been commenced in Alice Holt Forest.

Facilities for the study of the techniques of tree breeding were improved by the conversion of part of the walled garden and glasshouses at Grizedale Forest, Lancashire, for propagation by grafting, budding and the rooting of cuttings. The grafting of each major species will be studied at Grizedale, the first subject being Corsican pine. A promising technique has been worked out for this species, over three quarters of the grafts attempted under glass being successful. The testing of a method for the mass production of grafts in the open nursery has been commenced at Alice Holt, also with promising results.

The study of flowering and fruit production in forest trees continued, particular attention being paid to seed production in Corsican pine, Scots pine and beech. Cross pollination work was extended slightly during the spring of 1952, but as in past years the main effort was directed towards the selection and propagation of suitable materials for future use.

Corsican pine. The progress of work on Corsican pine is dealt with in some detail. The register of seed stands now contains over eighty entries totalling 1,439 acres. A tabular statement of the areas by age classes and site types clearly shows the lack of the older age classes.

The seed obtained from the cone induction trial reported in Forest Record No. 12 (1951) was of good quality. The germinative energy was high, the germination percentage after twenty days on the Copenhagen Tank ranging from sixty-seven to ninety-seven per cent. The health of the majority of the treated trees has not been affected.

Beech. A tabular statement of the area of seed stands is also given for this species. The register contains thirty-four classified entries totalling 1,079 acres. The chief weakness is now in the number of sources for North England and Scotland, and steps are being taken to fill the gap.

Larch. The establishment of the first seed orchard for the production of first generation hybrid larch began at Newton Nursery near Elgin, Morayshire. The orchard will be four acres in extent and will contain twelve Japanese larch clones and three European larch clones.

Establishment of Poplars

There are indications that, for the three sites and four varieties tested, unrooted sets gave almost as good results as more expensive forms of rooted cuttings and "stumps". In manurial experiments application of nitrogen produced the biggest effects; responses were also obtained to potash. New experiments have been laid down to test various mounding, mulching and weeding treatments, and to determine the effect of spacing in the nursery, for rooted cuttings, on survival and growth when planted in the forest. (Page 72).

Studies of growth and yield

47 permanent sample plots were established, 133 were remeasured and 7 were written off as a result of gale damage. 339 temporary sample plots were measured in broadleaved species, in order to provide the material for preparing provisional yield tables. Work on these tables has started and the revision of the conifer yield tables is well advanced. Among the more important special investigations were: an experiment designed to give some indication of existing and potential supplies of hazel coppice; a long term project undertaken jointly by the Forest Products Research Laboratory at Princes Risborough and the Research Branch of the Forestry Commission in order to study the effects of site and silvicultural treatment on timber quality; an estimate of the probable production of small

sized material between 3 inches and 1½ inches in diameter from conifer thinnings; and a study of the so-called "volume/basal area line" with a view to improving on existing methods of estimating the volumes of standing timber. Statistical activities have increased both in volume and in scope; seventy-two experiments were analysed, a few special computational tasks were undertaken, and three papers dealing with various aspects of this field have been prepared. (Page 75).

Forest Pathology

During the year under review comparatively little work has been carried to the stage where it can be written up for an Annual Report. For this reason consideration is directed to the enquiries dealt with by the section during the year. These totalled 148, of which 101 were concerned with forest pathology, and 47 with poplars, including their diseases. Thirty-nine of the enquiries involved visits. (Page 81).

Ninety-seven of the pathological enquiries are analysed in some detail, being divided under ten heads:—

Armillaria mellea	Botrytis cinera
Miscellaneous Fungal Diseases	Specialized Diseases
Decay	Soil Water Relations
Deficiencies	Wind
General Enquiries	Unexplained

and by the species of tree to which they referred. Fungal diseases which appeared with some frequency were Honey Fungus (*Armillaria mellea*), grey mould on conifers in nurseries (*Botrytis cinerea*), and leaf cast, caused mainly by *Lophodermium pinastri*, on pines. Among the physiological troubles, failure of transplanted trees to make fresh roots in cold waterlogged soil was commonest, affecting particularly Douglas fir and larch.

Forest Entomology

A survey of the status of larch sawflies carried out in various localities revealed that the Large Larch Sawfly, *Pristiphora erichsonii* Htg., was generally more numerous in 1951 than in 1950. Since this species is known to have caused major damage in the past, a close watch will continue to be kept on its distribution and population level. Other species of Larch Sawflies, including *Pristiphora wesmaeli* Tisch., *P. laricis* Htg., and *Anoplonyx duplex* Lep., were surveyed, and the results indicated that they continued to be found at low levels of population. Preliminary studies have been commenced on the biology of a number of species of both larch and spruce sawflies. (Page 87).

A survey of *Neomyzaphis abietina* Wlk. has yielded valuable data on its distribution and status under a wide range of conditions. This knowledge is being used as a basis for the selection of sample plot areas in which the population fluctuations and effects on rate of growth of Sitka spruce will be studied for a number of years.

The parasites of the Pine Shoot Moth, *Evetria buoliana* Schiff., were studied during the year. A consignment of *Ibalia leucospoides* Hochnw., a parasite of *Sirex* spp., was forwarded to New Zealand. Consultative and advisory work was continued.

Machinery

British Tractors. A Fowler Marshall V.F. is now coming into general use, whilst the Cuthbertson Buffalo is being used experimentally in Scotland. The possibilities of a greater use of half-track machines is being investigated.

Ploughing. Development of mounted ploughs on full track tractors and also on half-track tractors is proceeding.

Cableways. Cableways are now operating with a range of 600 yards.

Clearance of Derelict Woodland. Both the giant Rotavator and a tractor-operated grubber blade are on field trials.

Haulage over Soft Ground. Experiments on trailers with large-diameter low-pressure tyres are proceeding.

Fire protection. Development of light portable pumps is continuing.

Mechanisation of Nursery Operations. Machines suitable for spraying formalin and various weed killers have been adapted to suit forest nursery conditions. (Page 88).

Utilisation Development

The Utilisation Development section, on the recommendation of the Advisory Committee on the Utilisation of Home Grown Timber, carried out investigations on the utilisation of small sized conifer and hardwood thinnings and coppice. The marketing, by private estates, of small sized conifers in the South of England was studied. The home charcoal manufacturing industry was explored in some detail, primarily as a hardwood problem. A survey of the underwood industries dependent on coppice for their raw material was initiated, and field work on the estimation of the yield of hazel coppice reached an advanced stage. (Page 90).

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

Nutrition problems in forest nurseries

Dr. Crowther and Miss Benzian report progress in this work which is done under the guidance of a Sub-Committee (of the Research Advisory Committee), on Nutrition Problems in Forest Nurseries. The main results are summarised as follows:—

(1) Repeated top-dressings of ammonium sulphate gave much better one-year Sitka spruce seedlings than equivalent amounts of "Nitro-Chalk", in a third-year experiment in the Old Kennington nursery. This result is in harmony with the view that one of the effects from soil acidification or partial sterilisation may be to furnish ammonia in the soil in place of nitrate.

(2) In a series of single-year experiments, ammonium sulphate gave better results than "Nitrochalk" in three old nurseries but not in three new ones.

(3) Nitrogen fertilisers gave better results when applied as summer top dressings than when applied in the seedbed.

(4) Five other conifers gave broadly similar results to Sitka spruce in experiments on fertilisers, soil acidification and use of formalin.

(5) In parallel experiments at five nurseries, compost plots had fewer plants than fertiliser plots, and far fewer usable seedlings. Formalin increased mean heights in both old-established nurseries and new acid-soil nurseries, but in most of the nurseries formalin did not increase the plant numbers. The effects of formalin involve much more than the control of "damping-off".

(6) Winter applications of formalin were almost as effective as those given three weeks before sowing. Early application might be safer in general practice.

(7) Forest planting experiments in 1948 showed little difference between plants raised with compost or fertilisers.

(8) In forest planting experiments in 1950 there were heavy losses from soil wash, especially among one-year seedlings from Bagley Wood and the Kennington Nurseries. One-year seedlings from other nurseries survived well under these difficult conditions.

(9) The root systems of one-year Sitka spruce seedlings from experimental plots in several nurseries were classified independently by a large number of foresters and forest officers. There was a fair measure of agreement for most of these samples, but striking disagreements on Bagley Wood plants raised without formalin. Most foresters ranked these plants as "good" or "very good" largely because they had fibrous roots. A few members of the Research Branch staff shared Dr. Crowther's view that the fibrous nature of these root systems might be associated with fungal damage to the tap root and main laterals, and indicated pathological conditions. (Page 94).

Effect of Partial Sterilisation by Steam or Formalin on Damping-off of Sitka Spruce Seedlings in an Old Forest Nursery

This subject has been investigated by Dr. Warcup of the Botany School, Cambridge University, who found that three species of *Pythium* isolated from alkaline soil at Ampthill nursery in Bedfordshire caused damping-off of Sitka spruce seedlings and a root-rot of older plants. Part at least of the improvement in stocking and vigour of seedlings resulting from soil treatment with steam or formalin is attributed to control of these parasitic fungi. (Page 108).

Research into the Physical and Chemical Properties of Forest Soils

Mr. Rennie of the Forestry Department, Oxford University, reports results of studies in the fluctuations of aeration and moisture content of natural *Calluna* moorland soils, similar soils deeply ploughed, and twenty-year-old Sitka spruce plantations on similar ground. The varying capacity of different tree species to reduce waterlogging is mentioned, and also their different rooting habits. Cultivation experiments have shown that mere suppression of heather is not sufficient to make Sitka spruce grow on these heathlands, and that the effects of deep ploughing are due to other causes than heather suppression. Work on the nutrient status of these soils is in progress, and includes an experiment on the effects of adding ground limestone. (Page 108).

The Influence of Tree Growth on Soil Profile Development

Mr. Wright, working at the Macaulay Institute for Soil Research at Aberdeen, describes progress in his investigations. In studies of the nitrogen cycle in forest soils he found that the Lees perfusion method has yielded results of only limited value. Moisture changes in the soil are being studied by the gypsum-block resistance technique supplemented by other methods. The cyclic movement of nutrients between soil and crop is being studied. (Page 116).

Growth and Nutrition in Heathland Plantations

Dr. Leyton at the Department of Forestry, University of Oxford, reports that investigations into the growth and mineral nutrition of spruce and pine in young heathland plantations have revealed significant changes due to the removal of the heather (screefing) and the application, at various levels, of ground mineral phosphate. Removal of the heather in 1949, resulted in significant increases in dry matter and nitrogen content of the Spruce needles in 1950, and a corresponding increase in the height growth of the trees was observed in the following year (1951). The application of phosphate has also resulted in improved tree growth, but its effect appears to be indirect and associated with the nitrogen nutrition of the trees rather than with the improved phosphate status of the needles. Screefing has resulted in various other changes in the mineral status of the needles, but the exact significance of these changes has not yet been worked out.

Both Scots and Corsican pines have also responded to screefing and phosphatic fertilizing, but the changes have been less marked than in the case of the spruce. (Page 117).

Researches in Soil Mycology

Dr. Levisohn of Bedford College, London, continued experiments concerned with pre-mulching of seed beds and mulching of plants at Wareham heathland nursery. These have given substantial additional evidence of the rapid and significant changes brought about in the root infection of various tree species.

The separate phenomena of forking and infection in pine roots have been studied in pot experiments. These experiments have yielded results which may throw some light on the role played by the actual mycorrhizal infection in the life of the host plant. (Page 119).

Morphological Variation in Coniferous Species

Dr. Laing, Forestry Department, Aberdeen University, has continued his studies on four main lines, namely (1) the identification of hybrid larch in the very young seedling. This is found to be possible from an examination of the structure of the cotyledons of the newly germinated seedling. (2) A study of the variation in Japanese larch, in which it has been found that cone structure exhibits considerable variation. (3) The identification of European larch races by means of cone and seed, and (4) the morphological distinguishing characters between the "Shore pine" (*P. contorta*) and the "Lodgepole pine" (*P. murrayana*). These have been found to be sufficiently definite to distinguish them as separate species. (Page 120).

Study of the Natural Pinewoods of Scotland

Mr. Carlisle, of the Department of Forestry, University of Aberdeen, has commenced an investigation into the morphological and silvicultural variations in Scots pine of Scottish origin. This is combined with an ecological survey of the natural native pinewoods of that country. (Page 121).

Soil Faunal Investigations

Mr. Murphy, now working at Rothamsted, reports developments in the work commenced at the Imperial Forestry Institute on the soil Arthropod fauna of a heathland habitat in Allerston Forest, Yorkshire, before and after afforestation. The quantitative structure and vertical distribution of the fauna in natural and cultivated heathland planted with Sitka spruce is outlined. The populations obtained from these habitats represent 570,000 and 835,000

organisms per sq. metre respectively. In the natural heathland this total is concentrated in the first $2\frac{1}{4}$ inches of the profile, whereas in the cultivated site, in addition to the litter fauna, there is a considerable percentage in the raw humus "sandwich" created in the cultivation process. Examination of the qualitative composition indicates a marked preponderance of Acari in both sites. The dominant Prostigmate species of the two habitats are *Nanorchestes arboriger* Berl. and *Alicorhagia fragilis* Berl. respectively. (Page 123).

Research on Megastigmus Insects Infesting Conifer Seed

Mr. Hussey, of the Department of Forest Zoology, University of Edinburgh, has recorded three new species of *Megastigmus* during the course of his investigations this year. Parasites affecting 50% of the pest were recorded at three localities in Scotland. Studies on the life histories of parasite and host continued. Preliminary details are presented with emphasis on the important role played by rodents in the natural control of *Megastigmus*. Further work is in progress to ascertain at what stage of growth the Douglas fir cone is susceptible to oviposition. (Page 127).

The Nesting of Titmice in Boxes

Dr. Lack of the Edward Grey Institute of Field Ornithology reports on the fourth year of this enquiry, which has become the largest systematic recording of the nesting of any species ever carried out in Britain. 1951 results were similar to those of previous years. The first object of this experiment, namely to determine whether the population density of these insectivorous birds in managed forests can be increased, may be considered established. Work has commenced on the more difficult object of measuring the impact of these higher populations of titmice on the insect populations of the woodland. (Page 128).

Studies on the Relationship between Larch Canker and Trichoscyphella wilkommii

Mr. Manners of the Botany Department, Southampton University, reports on investigations into the larch canker fungus, frost, and other agents involved in the formation of cankers on larches. (Page 129).

Part I. Work carried out by Forestry Commission Staff.

FOREST TREE SEED INVESTIGATIONS

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

In November, 1951, the Alice Holt establishment was licensed as a Private Seed Testing Station under Section 2(1) of the Seeds Act, 1920. Since then, all routine testing of the tree seeds used by the Forestry Commission has been taken over from the official Agricultural Seed Testing Stations at Cambridge and Edinburgh. Under the licence, the laboratory can issue seed quality certificates only on forest tree seeds used or sold by the Department.

A new seed testing laboratory housing 20 Copenhagen tanks and 2 incubator type germinators, was completed in 1951. This has greatly eased the space situation and germination tests can now be carried out under more closely controlled conditions than in the past. The present capacity of the laboratory is 152 tests, excluding rapid chemical tests, per month. The estimated total number of tests required is 600-700 between November and March of each year. General views of the laboratory are shown in Plates I and II.

During the year, 600 seed purity and germination tests were completed. When the number of samples received exceeded the germinator space available, rapid chemical viability tests were applied, and the results checked by actual germination as germinator space became available.

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

The estimation of seed quality in cone samples from principal collection areas was continued. Examination of a large number of samples in 1950 (vide *Rep. For. Res.* March, 1951), showed large variation in germination quality and other characters of seed from different stands of the same species. In a number of cases large-scale collection of poor-quality seed was avoided by early examination of cone samples. During 1951, 110 cone samples were examined and reports issued.

Seed Extraction

A small forced draught, electrically heated, extraction kiln was built at Alice Holt. The kiln, which has draught control and thermostatic temperature control, is being used to study the effect of temperature, humidity and cone wetness on speed of extraction and seed quality. It is also being used for routine seed extraction from small lots of cones.

Seed Sampling Methods

A revised sampling procedure for extracting test samples from bulk seed lots was introduced. Variation between samples from a consignment can still

be high, and comparative trials with several sampling methods are now being carried out. Examination of the repeated halving method for obtaining the working sample from the test sample submitted, showed the method to be satisfactory for the majority of seed samples. In the few samples in which the percentage of empty seeds exceeds 20 per cent, the method gave significant underestimates of the percentage of sound seeds.

Germination Testing Methods

1951 was the third year in which experiments were carried out to test the use of 2, 3, 5-triphenyl tetrazolium bromide as a rapid seed viability indicator. The classification of embryo-staining groups has now been standardized for all the common conifer species. As a result of tests involving over one million seeds over the past three years, it has now been established that, using a standard test procedure, the embryo-staining method provides a satisfactory estimate of Copenhagen tank germinator results.

Germination values obtained with tetrazolium and Copenhagen tank methods were checked against replicated test sowings in nine contrasting nurseries in 1951. As in 1950, field germination was found to vary considerably from one nursery to another, but within any one nursery the actual germination of a range of seed qualities of a species is approximately proportional to the laboratory germination. In many of these test sowings the seedbeds are screened with three-eighths inch mesh wire netting to guard against losses by birds or rodents. Test sowings at Kennington Nursery, near Oxford, are shown in Plate III.

The tetrazolium embryo-staining method is now in regular use as an emergency test for samples on which a report is required within a few days. It is also used to supplement standard germinator methods. Sound seeds remaining ungerminated at the end of the test period in the germinator are tested by the chemical method, and the numbers of viable seeds are added as a "plus figure" to the germination per cent. Previously the practice was to add the total number of sound seeds remaining at the end of the test. This application of the chemical test has been found especially valuable for dormant and slow germinating species. Investigations have been continued into the most suitable laboratory methods for germinating tree seeds. For most conifer species the standard Copenhagen tank method using a fluctuating temperature has been found most satisfactory. For some species, notably Norway spruce, and *Abies* species, the incubator (filter paper) test is used. Where there is any doubt as to the best method, the test is carried out simultaneously by several different methods. Sterilised, heated soil beds are now in use for testing germination of large-seeded hardwood species.

Seed-borne Fungi

The growth of fungi on seeds during germination tests is often troublesome by retarding the progress of germination. The most profuse development of fungi occurs on seeds which have been stored for long periods, on bad seeds and on slow-germinating species. The majority of fungi occurring are undoubtedly superficial saprophytes developing from spores on the seed coat. These are probably of little or no importance when the seeds are sown in the field. Occasionally facultative parasites such as *Botrytis cinerea* are found. In view of the common occurrence of fungi on seeds under test, and the possible importance of some species on seeds sown in the field, Dr. S. Batko of the Pathology section was asked to assist in identification of species and examination of their effect on seed germination. The species most commonly found on seeds under test are as follows:—

Aspergillus nigricans Cooke=A. niger van Tiegh. On alder seeds, on *Robinia pseudoacacia* seeds.

Aspergillus flavus. Occasionally on seeds of *Robina pseudoacacia.*

Botrytis cinerea. Not common on seeds. On Norway spruce seeds and *Pinus sylvestris* seeds. The sclerotial stage has also been once observed on pine.

Chaetomium spp. Not uncommon on blotting paper, occasionally also on rotting seeds.

Cylindrocarpon spp. On seeds of Douglas fir.

Fusarium spp. On seeds of Douglas fir.

Rhizopus nigricans Ehr. On blotting paper and on seeds of *Thuja plicata.*

Oedocephalum glomerulosum Bull. Common on all species.

Penicillium spp. Fairly common on all seeds.

Stachybotrys alternans. Very common on blotting paper, occasionally also on rotting seeds.

Trichothecium roseum. Not common on seeds. Alder, Douglas fir.

Experiments will be done to test the effect of the several species on seed germination.

Seed Storage

Longevity of Oak and Beech Seed. The investigation into longevity of oak and beech seed under different storage conditions was continued. An experiment started in November, 1950, tested the importance of seed moisture content and the use of sealed containers, at storage temperatures ranging from 10°-36°F. Examination of samples of acorns from the several storage conditions, six months after starting the trial, showed that a temperature of 10°F. was fatal, while 25°F. was damaging, reducing germination capacity by 50%. Storage at room temperature and at a constant temperature of 36°F. was satisfactory, resulting in only a slight fall in seed viability after storage for six months. Pre-drying the acorns to 70% moisture content (based on dry weight) before placing in store was found highly damaging.

Tests after eighteen months storage showed all seeds to be dead, except those stratified in moist sand or peat in an unsealed contained at 36°F. Even in this treatment, however, seeds tested in May, 1952, showed a germination of only 33% compared with 85% when the seeds were placed in store in November, 1950. Similar tests on beech showed that no seed remained alive after eighteen months storage, except in those cases where the seed was stratified in an unsealed container at 25°F. Under this condition the stored seed showed a fall in germination from 80% in November, 1950, to 50% in May, 1952.

The use of airtight containers, or pre-drying the seeds before placing them in store, had no significant effect on longevity of either species.

Longevity of Conifer Seeds. Test samples of European larch, Japanese larch, Corsican pine, Norway spruce and Sitka spruce were placed in contrasting storage conditions in September, 1950, to determine the most satisfactory methods for prolonged storage of these species. Tests carried out after one year showed that no loss of viability occurred in seeds stored dry in sealed containers at room temperature or at a temperature of 36°F. Seed in unsealed containers showed an increased moisture content and a marked fall in viability. Seeds in this trial will be examined at yearly intervals as long as any seeds remain viable.

EXPERIMENTAL WORK IN NURSERIES

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

Partial Sterilization of the Soil

Steaming methods

At Newton Nursery, Morayshire, a large scale steaming experiment was conducted on a light soil in early April, using 50 ft. x 3 ft. steaming units. The "canopy" or hood system was employed. The two treatments were first, steaming until soil at a six-inch depth reached 180°F., after which steam injection was stopped (treatment A), and secondly (treatment B) steaming until the soil at a six-inch depth reached a temperature of 180°F., after which steam injection was continued for an additional ten minutes. The treated areas were sown with Sitka spruce, and demonstration plots of Scots pine, Douglas fir and Norway spruce were also sown. The results of the experiment are given in Table 1.

EFFECT OF TWO LEVELS OF STEAMING ON WEEDING TIMES AND THE MEAN HEIGHTS AND NUMBERS PER SQUARE FOOT OF ONE-YEAR SITKA SPRUCE, SCOTS PINE, DOUGLAS FIR AND NORWAY SPRUCE SEEDLINGS

Table 1

		Sitka spruce			Scots pine		Douglas fir		Norway spruce	
Treatment	Average steaming time (minutes)	Mean Ht. in in.	Nos. per sq. ft.	Weeding times Minutes persq.yd.	Mean Ht. in in.	Nos. per sq. ft.	Mean Ht. in in.	Nos. per sq. ft.	Mean Ht. in in.	Nos. per sq. ft.
Control	0	1.7	107	93.3	2.5	119	1.7	115	4.1	69
A	33	2.3**	115	9.3*	2.5	120	2.3	139	5.2	65
B	42.4	2.4**	109	12.1*	2.4	118	2.3	129	5.1	78

** Highly significantly greater than the control.

* Highly significantly less than the control.

The height growth of Sitka spruce on sterilized soil was highly significantly greater than on unsterilized soil. There was no benefit from the additional ten minutes of steaming. The number of seedlings was not significantly affected, but total weeding times for the whole season were drastically reduced on the steamed ground. Scots pine did not benefit from the soil sterilization, but Douglas fir and Norway spruce both produced a marked increase in height growth. The yield of Douglas fir showed an increase on sterilized ground. Variations in the number of Norway spruce seedlings were inconsistent.

This experiment confirms previous indications that using the hood system of steam sterilization, larger areas of seedbed (150 sq.ft.) can be successfully treated at any one time, than with the standard Hoddesdon pipes (60 sq. ft.).

Costs are therefore greatly reduced. Steaming times were longer than the usual twenty minutes given in previous years.

Formalin and Steam—Residual Effects on Second Year Sowings

At Tulliallan, Fife, an experiment (3.P.50.C. Extn. P.51) designed to compare steam and formalin on areas treated with and without compost, nitrogen and combined dressing of potash and phosphate in 1950, was resown in 1951 without further treatment other than top dressings of nitrochalk given to plots receiving nitrochalk in 1951. Sitka spruce sown on steam-treated plots showed a small (0.11 inch) but highly significant mean height increase over plots not treated with steam. Weeding times were highly significantly less on steamed ground (3.8 minutes per sq. yd.) but the number of seedlings was not significantly affected. Formalin sterilization produced no residual benefit in any respect. For some unknown reason in compost-treated plots the number of seedlings per sq. ft. was significantly reduced; and addition of nitrochalk increased the mean seedling heights by 0.1 inch.

Formalin Sterilization

Experiments were laid down at Inchnacardoch, Inverness-shire; Mabie, Dumfries-shire; Benmore, Argyll; and Newton, Morayshire, to test the efficacy of "Sisalkraft" paper and water as soil sealing agents following formalin applications at rates of 0.1 and 0.05 gallon of 38 per cent formalin in suitable amounts of water. Soil sealing agents were used to determine whether the smaller amount of formalin could be used to produce the same effect as the larger amount on an unsealed soil. Results at all four nurseries showed that both concentrations of formalin highly significantly increased the mean seedling heights of Sitka spruce.

Sealing the soil by water or "Sisalkraft" had no outstanding effects on subsequent seedling growth or numbers at any of the four nurseries, but sealing the soil with "Sisalkraft" produced a significant reduction in weeding times at three of the four nurseries. The fact that the paper cover reduced the weeding times suggests that the aim was achieved to some extent, but the improvement was small and not significantly shown in growth responses.

On a seven-year-old portion of Inchnacardoch heathland nursery, formalin produced a highly significant benefit in height growth to Sitka spruce seedlings and had no marked effect on seedling numbers. Earlier trials of formalin on new heathland nurseries did not produce height growth responses. A similar trial was laid down in the oldest part of Devilla heathland nursery, but "cutworm" attack in late summer caused the experiment to be abandoned.

An experiment on an old established nursery soil at Kennington nursery, Oxford, testing the effect of formalin dosage, showed that application rates ranging from 0.05 to 0.20 gallon of 38% formalin per square yard prior to sowing, greatly improved growth of Sitka spruce seedlings. Application of 0.10 gallon of formalin in 0.50 gallon of solution with water increased the seedling mean height from 0.82 inches on untreated plots to 2.62 inches on treated plots. Application of 0.10 and 0.20 gallon of 38% formalin per square yard gave similar results, and both rates were appreciably better than the 0.05 gallon rate.

The total volume of solution in which a given quantity of formalin is applied has a marked effect on the growth response. Application of any of the above rates of formalin in 0.5-1.0 gallons of solution per square yard gave better results than application of the same rates in 0.25 gallons or less, of solution per square yard. (Vide Table 2).

EFFECT OF VOLUMES OF SOLUTION CONTAINING EQUIVALENT AMOUNTS OF FORMALIN, ON THE GROWTH AND PRODUCTION OF ONE-YEAR SITKA SPRUCE SEEDLINGS.

Table 2

Treatment Volume of Solution per sq. yd.	Total No. of Seedlings per plot of $1\frac{1}{2}$ sq. ft.	Mean ht. inches
1 gallon	199	2.73
$\frac{1}{2}$,,	207	2.51
$\frac{1}{4}$,,	195	1.98
$\frac{1}{8}$,,	217	1.66
Sig. Diff. (P=0.05)	29	0.43

None of the application rates tested had any effect on seedling numbers. The reduced effect of lower total volume applications on growth is probably due to inadequate penetration into the soil.

"D-D" Soil Fumigant Sterilization

Work was continued for a second year at Newton, Benmore, Inchnacardoch and Fleet on testing the efficiency of Shell "D-D" soil fumigant as a seedbed soil sterilizing agent, in comparison with formalin. As in 1950, three concentrations of "D-D" were used (150 lb., 300 lb. and 600 lb. per acre) and these were injected into the soil at a depth of four inches four weeks before sowing. Two or three lines of injection points were used for injecting the "D-D" into the soil, and two weeks before sowing the beds were cultivated to allow residual vapours to escape.

Periodic germination assessments in June and July showed that at Newton, Fleet and Inchnacardoch neither the concentration of "D-D" nor the number of injection points per plot had any marked effect upon the rate of germination in the early stages. At Fleet, formalin had significantly accelerated germination by mid-July. At Benmore, where results were erratic, "D-D" and formalin highly significantly reduced the rate of germination.

At most nurseries results at the end of the growing season showed that there were no significant differences for mean heights, total numbers or weeding times of Sitka spruce plots between the three different levels of "D-D" or between the two methods of injecting "D-D" into the soil. Exceptions were at Benmore where injecting the chemical in three lines highly significantly reduced weeding times in comparison with plots injected with "D-D" in two lines, and at Newton where injecting with three lines of "D-D" per bed produced significantly taller seedlings (0.1 inches) than beds injected with two lines of "D-D" per bed.

The overall effect of "D-D" was to highly significantly increase the mean heights of seedlings at Benmore and Inchnacardoch, and to significantly reduce weeding times at Benmore and Fleet; it had no appreciable effect on the final yield of seedlings, at any of the nurseries. In comparison with formalin, "D-D" did not produce such tall seedlings and its effect upon weed growth was very much less. During the first two years of experiments with "D-D" as a soil sterilizing agent for Sitka spruce seedbeds, it has not compared favourably with formalin in spite of its cheapness and low cost of application.

Soil Acidification

The 1950 experiment at Widehaugh Nursery in which acidification and partial soil sterilization with formalin were carried out, was resown with Sitka

spruce seed with no further treatment except that all plots which had been given the standard N.P.K. treatment in 1950 were again treated with N.P.K. at standard rates. Results showed that none of the acidification treatments (4% sulphuric acid at 1.1 gall./sq. yd., flowers of sulphur at 2.2 oz., 4.4 oz. and 6.6 oz. per sq. yd. and ammonium sulphate at 1.1 oz. per sq. yd.) produced any significant benefit or detriment to the height growth of the seedlings. All acidification treatments other than the 4.4 oz. of flowers of sulphur significantly increased the numbers of seedlings, and the 6.6 oz. and 2.2 oz. levels of flowers of sulphur highly significantly increased the weeding times per plot. Other acidification treatments increased the weeding times slightly but not significantly.

The residual effect of formalin sterilization produced highly significant increases in mean seedling heights and total numbers, but it had no marked effect upon weeding times. Plots treated with fertilizers produced a considerable response in seedling height growth and weeding times.

Manuring

Placement of Fertilizers

Placing drills of phosphate and potash, alone and in combination, one inch below broadcast and drilled seed indicated visually that drilled phosphate in particular produces a very marked increase in height growth. Plots at Fleet having broadcast seed, and drilled potash and phosphate, produced seedlings immediately above the drilled fertilizers 1½ to 2 inches taller than seedlings growing between the drilled fertilizers. This general result was repeated at Newton, Tulliallan, Inchnacardoch and Wauchope on a less striking scale. It confirms results obtained in similar experiments during previous years in that drilled phosphate produces very beneficial results at Fleet nursery but not elsewhere. The reason for this is obscure.

Forms of Applying Nitrogen to Seedbeds

The 1949 experiment, which compared nitrochalk, flash, formalised casein, hoof and horn meal, fish guano, and vegetable meal, as nitrogenous manures for application to nursery seedbeds, was repeated for a final time at each of six nurseries. This year it was conducted on formalin-sterilized soil. Results were similar to results obtained in previous years, namely that at most nurseries, flash and formalised casein produce the tallest and largest numbers of seedlings. Hoof and horn meal and fish guano produce reasonably tall seedlings, while fish guano and vegetable meal greatly reduce the total yield of seedlings. There were no marked differences in either mean heights or total numbers between plots treated with nitrochalk, as one third of the weight applied before sowing followed by two equal dressings applied in early and late July, and plots in which the same total quantity of manure was applied in two equal top dressings in early and late July.

As in 1950, germination assessments showed that the bulky organic manures—fish guano and vegetable meal—produce a serious depressing effect upon the rate of germination.

Compost Trials

The experimental wheat straw and sawdust composts prepared in 1950, using synthetic nitrogenous activators, were applied and tested in Sitka spruce seedbeds in 1951. The trials were conducted at two nurseries, one on an acid heathland soil and one on a loamy broadleaved woodland soil. All the test

composts were applied to the seedbeds at the equivalent of twenty tons per acre (net) a few weeks prior to sowing. Assessment of the crop at end of 1951 showed that sawdust composts in general gave poor results, with the outstanding exception of a compost consisting of mixed sawdust, formalised casein and ground limestone (vide table 3). One year-old and two-year-old composts of hops and sawdust were found to be ineffective. There were no large differences in the appearance of the composts at the time of application, and the results are difficult to interpret except in terms of increased nitrogen supply in the compost containing formalised casein. The addition of ground limestone to straw and hops composts, to relieve acid conditions during the composting process, had no effect on the appearance or manurial value of the final compost.

Wheat straw composted with formalised casein and ground limestone gave good results, while standard straw and hops compost gave no significant growth improvement on either soil. On both heathland and woodland soils, composts of straw and ammonium sulphate, with and without ground limestone, gave equally good results.

EFFECT OF APPLICATION OF STRAW OR SAWDUST COMPOST ON THE GROWTH OF ONE-YEAR SITKA SPRUCE SEEDLINGS

Table 3

Treatment	Seedling Mean Height at one-year (inches)	
	Heathland Soil	Woodland Soil
1. Untreated	0.88	0.84
2. Straw + ammonium sulphate	1.42	1.74
3. Straw + ammonium sulphate + ground limestone	1.90	1.65
4. Straw + formalised casein	1.64	1.85
5. Straw + hops	1.02	1.18
6. Sawdust + hops (2 year compost)	1.29	1.09
7. Sawdust + hops (1 year compost)	1.02	1.09
8. Sawdust + formalised casein + ground limestone	1.65	2.04
Sig. Diff. (P=0.05)	0.52	0.53

The results of this trial serve to underline the importance of added nitrogen in the compost, and also the difficulty of judging the manurial value of a compost by eye inspection of its physical characters at the end of the composting period. For example straw and ammonium sulphate, which appeared unsatisfactory because of dryness and incomplete breakdown, gave good results on both soils, while straw and hops which appeared to be an excellent compost having a dark moist amorphous appearance gave poor results. After application of incompletely broken down, dry composts there is a risk of soil drying and seedling losses because of soil consolidation difficulties. Special attention was paid to seedbed consolidation throughout this trial, and none of the composts had any effect on seedling numbers, although commonly the effect of compost application is to increase growth and depress seedling numbers.

An experiment was completed which tested the importance of the degree of decomposition of a compost when it is applied to the soil. Seedbed trials

of a series of straw/hopwaste composts, which had been composted for periods ranging from one to seven months, showed no difference between composts in their effect on growth and production of Sitka spruce seedlings. It is not possible to draw any reliable conclusions from this comparison, as breakdown was rapid, and even the straw composted for only one month before application was in a fairly advanced stage of decomposition.

A series of experimental composts was prepared in 1950 to compare the merits of hopwaste, poultry manure and fish meal as activators for composting bracken or straw. Contrasting effects were obtained in 1951 when these composts were applied as seedbed dressings on an acid heathland and an agricultural type established nursery soil. Bracken or straw with fish meal, and bracken with hops, more than trebled the production of usable Sitka spruce seedlings per pound of seed sown on the heathland soil, while on the agricultural soil no compost treatment had any effect. The small growth response to compost treatment is a common feature of older established nursery soils, and the use of composts on such areas appears a doubtful economic proposition when judged in terms of the effect on immediate crop yields.

Soil Mulching Trials

The experiment started at Wareham heathland nursery during 1950, to examine the beneficial effects of mulch application, was sown with Sitka spruce and *Pinus contorta* as test crops in 1951. The experiment was designed to test the size of the effects of the late Dr. M. C. Rayner's technique of applying a green bracken mulch to composted ground during the summer and winter prior to cropping with tree seedlings.

In the present trial, compost was worked into the soil in May, 1950, at a rate equivalent to 20 tons per acre. The mulch treatments were applied immediately afterwards and allowed to remain on the soil until seedbed preparation in March, 1951. In the mulch treatments a comparison was made between a heavy green bracken mulch, and a mulch consisting of inert cellulose fibre. Unmulched plots were rough cultivated and treated as bare fallow throughout 1950. In March, 1951, all mulches were lifted, seedbeds prepared and seed sown with no further manurial treatment. Assessment of the seedling crop at the end of the season showed that both compost and mulch treatment had a marked effect on seedling growth in 1951. (See Table 4).

EFFECT OF COMPOST AND MULCH APPLICATION ON THE GROWTH AND PRODUCTION OF ONE-YEAR SEEDLINGS OF SITKA SPRUCE AND PINUS CONTORTA (WAREHAM 1951)

Table 4

(*a*) *Mulching*

Treatment	Sitka Spruce 1 + 0		Pinus Contorta 1 + 0	
	Mean Height inches	Number of Usable Seedlings per lb. of seed	Mean Height inches	Number of Usable Seedlings per lb. of seed
0. No mulch	1.29	27,600	1.30	10,900
1. Inert cellulose mulch	1.11	18,500	0.99	5,500
2. Bracken mulch	2.01	59,700	1.68	17,300
Sig. Diff. (P=0.05)	0.34	—	0.28	—

(*b*) *Compost*

Treatment	Sitka Spruce 1 + 0		Pinus Contorta 1 + 0	
	Mean Height inches	Number of Usable Seedlings per lb. of seed	Mean Height inches	Number of Usable Seedlings per lb. of seed
0. No compost	1.09	21,100	1.16	8,700
C. Compost	1.85	49,400	1.48	13,700
Sig. Diff. (P=0.05)	0.27	—	0.23	—

Neither compost or mulch treatment had any effect on total seedling production of either species. Compost application in the spring of the season before sowing greatly increased the height growth of Sitka spruce. *Pinus contorta* was also improved, but the effect was smaller.

Bracken mulch greatly increased the growth of Sitka seedlings and slightly improved the growth of *Pinus contorta*. Inert cellulose mulch, on the other hand, had practically no effect on Sitka spruce and actually depressed the growth of *Pinus contorta* seedlings. The growth benefits from compost treatment were entirely unaffected by subsequent mulch or bare fallow treatments.

The superiority of green bracken mulch over the inert cover suggests strongly that a large part of the bracken effect is due to nutrients, possibly potash, being leached from the bracken into the soil below. The effect of mulching is large in the case of Sitka spruce, and experiments are being continued to test the effects of other types of mulch and more complete soil covering.

Organic and Inorganic Manuring in Heathland and Woodland Nurseries

An experiment designed to compare the effects of greencrop and compost on newly opened heathland nurseries was started at Broxa Moor, Langdale Forest, Yorkshire.

At Littleburn Nursery, Kilcoy Forest, Ross-shire, the same experiment started in 1949 was re-sown with Sitka spruce seed for the second year. Plots receiving compost in the previous year were retreated with compost at half rates (5 lb./sq. yd.) and phosphate, potash and nitrogen were given at standard rates to plots treated with these manures in the previous year. End-of-growing-season results indicated that complete fertilisers applied to ground treated with greencrop two years previously, or to ground treated with neither greencrop nor compost, produced the tallest and greatest yield of seedlings. Compost had a reducing effect on both mean heights and total numbers, whereas greencrop-treated ground increased mean heights significantly and had no significant effect on total numbers. There is no satisfactory explanation available for these adverse second year residual effects of compost.

Long-Term Fertility Demonstrations

The long term fertility demonstration at Inchnacardoch was continued into its thirteenth year.

At Teindland, Morayshire, woodland nursery, the Nursery Nutrition Advisory Sub-Committee demonstration continued into its second year. This demonstration compares artificial fertilisers only, compost only, and combinations of the two, with untreated ground. End of season assessments are reproduced in Table 5. These indicate that artificial fertilizer alone is still the most satisfactory and productive treatment.

TEINDLAND WOODLAND NURSERY FERTILITY DEMONSTRATION, END-OF-SECOND-YEAR HEIGHT AND NUMBER PRODUCTION FIGURES FOR SITKA SPRUCE AND PINUS CONTORTA ONE-YEAR SEEDLINGS

Table 5

Treatment	Sitka spruce			Pinus Contorta		
	Mean hts. in.	Nos. per sq. ft.	Nos. per sq. ft. over 1½ in. tall	Mean hts. in.	Nos. per sq. ft.	Nos. per sq. ft. over 1½ in. tall
Control	0.5	140	1	1.0	131	6
Artificials only	1.7	152	84	2.2	127	98
Compost only	0.8	139	11	1.3	123	24
Artificials and compost	1.2	146	32	1.9	135	88

At Newton the Nursery Nutrition Advisory Sub-Committee demonstration comparing greencropping, compost, artificial fertilisers, sterilization and continuous cropping, alone and in various combinations, was sown for the first time. Results at the end of the first season indicated that sterilization treatments produce the greatest benefit to height growth, while artificial fertilisers also producing considerable response. Neither compost or greencrop had any appreciable effect on mean heights, but organic manures in combination together slightly reduced the total numbers of seedlings. The reduction in seedling numbers on areas treated with bulky organic manures in spring was common to many Scottish nurseries in 1951. A dry period of weather immediately following seed sowing is probably the main cause of these reductions. The greencrop was not expected to have any immediate beneficial effect, but rather a long-term one in maintaining fertility in comparison with continuous cropping with conifers.

Grass Leys and Greencrops

The experiment started on an old, regularly cropped section of Kennington nursery, Oxford, to test the value of grass and clover ley for improving soil productivity, was concluded. In 1951, all plots were resown with Sitka spruce to examine the residual effects of ley and fallow treatments applied in 1947 and 1948. As in 1949 and 1950, no improvement of soil productivity was detectable as a result of continuous ley during 1947 and 1948. An interesting and unexpected effect was that plots continuously fallowed during 1947 and 1948 showed a significantly greater total production of Sitka seedlings in 1951 than plots under ley in 1947-48. Land cropped with trees annually since 1947 showed similar production figures to the ley plots in 1951.

In a trial at Wareham heathland nursery it was found that incorporation of a green crop of oats, ryegrass and tares in 1950, prior to mulching with bracken for the remainder of the season, resulted in poorer tree seedling growth in 1951 than continuous mulch soil cover throughout 1950. The growth difference was most pronounced on spruce, larch, and pine seedlings; beech seedlings were unaffected.

Seedbed Watering and Irrigation

A trial started at Kennington Nursery, Oxford, in 1950 was repeated in 1951, using an overhead sprayline sprinkler system to compare two contrasting watering regimes in their effect on the growth and production of one-year conifer seedlings. The two irrigation treatments were:—

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

The rainfall during the growing season was appreciably lower than during the same period in 1950, but it was again above the average for the nursery. (vide Table 6).

RAINFALL, AND IRRIGATION WATER APPLICATION, MAY—SEPTEMBER, 1951

Table 6

Month	Average Rainfall for Nursery (inches)	1951 Rainfall (inches)	Irrigation Water Applied (inches)	
			Treatment 1	Treatment 2
May	1.8	2.39	1.25	0.93
June	1.8	1.23	2.97	1.56
July	2.6	1.29	3.89	3.07
August	2.0	4.18	0.13	—
September	2.2	2.29	0.88	—
TOTAL	10.40	11.38	9.12	5.56

Irrigation treatments were applied most frequently during the two dry months of June and July. There was a dry spell during the important germination period in the second and third weeks of May when irrigation water greatly improved the progress of germination, particularly in the case of Sitka spruce. Assessment of stock at the end of the growing season showed that both irrigation treatments increased growth and total seedling production for this species. (Vide Table 7).

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

Table 7

Treatment	Total Seedling Production per lb. of seed sown	Seedling mean Height at End of Season (inches)
0	49,000	1.77
1	89,000	2.26
2	82,000	2.19

As in the 1950 trial, irrigation almost doubled total seedling production compared with unwatered plots. The growth effects do not appear large when expressed in terms of seedling mean height, but the sum of production and growth effects resulted in a doubling of the number of *usable* one year seedlings at the end of the year. There were no significant interactions between irrigation and compost or fertilizer manurial treatments.

Sitka spruce showed the largest response to watering of any of the species tested. Watering increased seedling production of Corsican pine and Japanese larch, but had no significant effect on Douglas fir. Neither regime affected the seedling growth of any of these three species.

A similar trial, on a larger scale, was carried out on rising one-year seedbeds of Sitka spruce, Norway spruce, Scots pine, and Japanese larch at Widehaugh

Nursery, Northumberland, in 1951. Two irrigation treatments were applied as follows:—

(1) Soil maintained as near field moisture capacity as possible.
(2) Soil allowed to develop a moisture deficit equivalent to 2 inches of water by the end of August.

The rainfall at Widehaugh during May, June and July was below the monthly average for the locality, but the rainfall in August was well above average and no irrigation was necessary on any of the plots from early August onwards. It was found impossible to conform to treatment 2, as the heavy rain in August made up the soil moisture deficit which had been gradually allowed to build up from mid-May onwards. The highest deficit reached in this treatment was 1.35 inches at the end of July.

A total of 5.84 inches of irrigation water was applied in treatment 1, during the period May 19th to July 31st, compared with 4.13 inches in treatment 2 in the same period. The effect of both treatments on seedling growth was negligible, but the total production of seedlings was greatly increased in the case of Norway spruce, and appreciably increased for Sitka spruce and Japanese larch. The growth and production of Scots pine was unaffected. The growth of all species was poor in the Widehaugh trial and it seems likely that some factor other than moisture was limiting. This trial is to be repeated in 1952, with the addition of a partial soil sterilisation treatment as a possible remedy for the overall low productivity found in 1951.

Chemical Control of Weeds in Forest Nurseries

A. Weed Control in Seedbeds

Following on the promising results with mineral oils in 1949 and 1950 experiments, a series of "user" trials were carried out in seven nurseries in 1951, with the object of testing the best treatments on a practical scale. Two grades of vaporising oil and white spirit were applied as pre-emergence sprays at 100 ml./sq. yd., and as post-emergence sprays at 40 ml./sq. yd. to rising one-year seedbeds of Corsican pine, Scots pine, Norway spruce and Sitka spruce.

All pre-emergence treatments were successful. The weed control was good in all nurseries, and there was no evidence of damage to the tree crop except in cases where seedlings were emerging at the time of application. The results of post-emergence spraying were most variable. In all cases application of vaporising oil as a post-emergence spray damaged the tree seedlings, often fatally. Post-emergence application of white spirit was more successful, but the results were variable; in some instances severe damage was done to the tree crop. The weather conditions and stage of growth of the tree seedlings at the time of spraying undoubtedly affect their sensitivity. Both pine and spruce seedlings are most sensitive during the first few days after emergence and for two or three weeks after the seed testa has fallen. Hot sunny weather at the time of spraying also appears to increase the sensitivity of the crop to treatment.

The variable crop damage following post-emergence mineral oil spraying in 1951, has arrested practical development of this treatment until the causes of variation can be investigated in more detail. Trials to test the sensitivity of seedlings of a range of species to post-emergence white spirit applications showed that *Thuja plicata* appears to be resistant, and rising one year seedlings were undamaged after as many as three applications of white spirit at 60 ml. per square yard between early July and late September. Similar applications to Japanese larch and Douglas fir resulted in a severe growth check after the second application. A single application of 60 ml. white spirit per square yard in mid-summer caused negligible damage to these species. As for pine and spruce,

spray treatments shortly after seedling emergence or just after the testa has fallen were the most damaging.

Experiments comparing the effectiveness of several pre-emergence seedbed weed control treatments were completed. Treatments included spraying prior to tree emergence with dilute sulphuric acid, allyl alcohol, iso-propyl phenyl carbamate emulsion, sodium chlorate and vaporising oil. All treatments were compared with flame gun treatment of the bed and normal handweeding. Experiments in two nurseries on beds of Corsican pine and Sitka spruce showed vaporising oil applied at 100 ml. per square yard three to four days before tree emergence, and 0.5 per cent sodium chlorate at 600 ml. per square yard 7 days after sowing, to be the best treatments. No crop damage was done, and both treatments reduced weeding costs for the season by 85 per cent compared with a 45 per cent reduction following flame gun treatment.

Spraying with 1 per cent sulphuric acid or iso-propyl phenyl carbamate emulsion greatly reduced weeds, but also reduced the number of trees of both species. Similarly 0.2 per cent allyl alcohol at 5 litres per square yard, seven to ten days before sowing, almost eliminated weedgrowth, but drastically reduced the growth and number of Sitka spruce seedlings; Corsican pine was less affected; growth was reduced but no reduction in seedling numbers occurred.

B. Weed Control in Transplant Lines

Application of vaporising oils or white spirit mineral oil for control of weeds in transplant lines was found to give variable results. Weed control was satisfactory, but the amount of damage to the tree crop varies greatly according to species and the stage of application.

Mid-August application of vaporising oil or white spirit at 100 gallons per acre as an overall spray caused foliage scorch of rising one-plus-one transplants of Scots pine, Corsican pine, Japanese larch, beech and oak. On Scots pine and Japanese larch many terminal shoots were killed, while on oak and beech all young growth was killed back and mature leaves showed severe burning. Lawson cypress and Norway spruce showed only slight foliage damage, and no growth check was apparent. White spirit also caused crop damage, but less severe than that following vaporising oil treatment.

The same treatments applied to other plants one month earlier, in mid-July 1951, caused negligible damage to spruce and pine transplants.

The most satisfactory results were obtained by restricting the oil sprays to the soil surface and the stem bases of the transplants, by means of a hooded sprayer. This technique resulted in high degree of weed control and negligible damage to the most sensitive tree species.

Season and Date of Lining-out

The 1949 lining-out experiment was repeated at five northern nurseries, viz. Inchnacardoch, Tulliallan, Benmore, Mabie, and Harwood Dale, Allerston Forest, Yorkshire, using rising one-year and rising two-year Scots pine and Sitka spruce seedlings. Lining-out took place at intervals from early August 1950 to mid-April, 1951. As in 1949, the seedlings were separated into height classes at the time of lining-out in order to determine the relationship between initial size and subsequent survival and growth.

Rising One-Year Scots Pine. Seedlings one to two inches high, lined out in late autumn and early winter, suffered heavily from frost-lift. Early mid-spring lining-out produced the greatest yield of survivals. For seedlings two inches and over, from mid-October onwards was a safe and suitable period for the operation at most nurseries.

Rising Two-year Scots Pine. All height classes tried at Tulliallan and Mabie, and all classes under four inches at Inchnacardoch, gave unsatisfactory results at all the times under test. At Inchnacardoch plants over four inches lined out in early August, early September and mid-October proved to be the most satisfactory. All height classes and dates gave successful results at Benmore and Harwood Dale.

Rising One-year Sitka Spruce. No treatment was successful at Inchnacardoch, but at the remaining nurseries March to April treatments were outstandingly the best for all height classes from one to four inches.

Rising Two-year Sitka Spruce Seedlings. There was some evidence that it is possible to line out plants over 6 ins. tall successfully in August at Harwood Dale and Inchnacardoch. At Tulliallan six-inch plants lined out in April were the only successful group; whereas at Benmore and Mabie, November to April proved a suitable period for plants over 3 inches tall.

Miscellaneous

Soil Heating

At Tulliallan a trial was started to determine the effect of artificial bottom heat on Sitka spruce seedlings. A large frame was filled with four separate soil types above electrically heated soil warming wires. The soil types used were: John Innes compost No. 2; Devilla pinewood soil fortified with compost at 21½ tons per acre; a heavy clay loam from Tulliallan with compost at 30 tons per acre; a medium loam from Tulliallan with compost at 21½ tons per acre. All soils were sterilized with formalin and given the standard dressing of nitrogen, phosphate and potash.

Seed sown on April 7th was given bottom heat for 52 days to maintain surface soil temperatures of approximately 65°F. After this period the heating was stopped and the plants were allowed to "harden off". Subsequently the overhead glass was removed and the plants were allowed to continue growing under normal Tulliallan conditions. Table 8 shows the final assessment figures at the end of the growing season.

END OF SEASON HEIGHTS AND NUMBERS OF ONE-YEAR SITKA SPRUCE SEEDLINGS GERMINATED AND GROWN ON FOUR SOIL TYPES ARTIFICIALLY HEATED TO PRODUCE A SURFACE TEMPERATURE OF 65°F FOR 7 WEEKS

Table 8

Soil type	Mean Height in inches	Percentage over 1½" tall	Numbers per sq. ft.
John Innes No. 2	3.9	98%	104
Pinewood soil + compost	5.5	100%	89
Heavy clay loam + compost	5.7	98%	101
Medium loam + compost	4.6	99%	83

Sitka spruce raised during the same period in Tulliallan nursery on compost treated soil, but without bottom heat and overhead glass, produced seedlings from 0.5 inches to 1.0 inches tall. The results obtained indicate that bottom heat can be used to ensure the production of "usable" one year seedlings of species which normally require two years in outdoor seedbeds. The economics of such soil heating have not yet been fully worked out.

Root Pruning

Experiments were started at Tulliallan and Newton to determine the effect of root pruning one-year and two-year Scots pine and Japanese larch seedlings. The main object of the work is to find whether root-pruned seedlings produce root systems and heights comparable to similar plants lined-out. If successful the technique may considerably cheapen the production of planting stocks in established nurseries. In the experiments the two species have been sown at three sowing densities, viz. normal, half normal, and quarter normal, so that in the two latter densities greater root and shoot space will be given to the plants which will be remaining two or three years in the beds.

Maleic Hydrazide as a Growth Inhibitor

At Wykeham, Tulliallan and Mabie, Sitka spruce and Douglas fir plants were lined out in October in readiness for spraying with concentrations of 0.2%; 0.1%; 0.075%; 0.05%; and 0.025% solutions of maleic hydrazide in water. Maleic hydrazide is known to have a growth-inhibiting effect upon certain plants and it is possible that it may prove useful in retarding the growth of "stand over" beds of surplus seedling or transplant stocks which would otherwise have to be destroyed. Unfortunately the plants at all centres suffered severe loss through wind blast and frost lift, and accurate assessments of the experiment were impossible. The chemical is being tried in 1952 on one-year seedbeds of a variety of species.

Growth Promoters

At Tulliallan and Quarry Wood (Morayshire) a commercial mixture of vitamins and hormones was applied on a trial scale at recommended strengths in solution, to seed and rising seedlings of Sitka spruce. End of season assessments indicated that the material had little or no effect on the height growth or numbers of this species.

Nursery Machinery

Fertilizer Application and Seed Sowing

A number of trials were carried out in 1950-51 to test the suitability of several existing commercial machines for use in forest nurseries. A satisfactory machine for broadcast application of fertilizers to seedbeds was found, and it is now being fitted with a precision delivery control to permit its use as a broadcast seed sower.

Formalin Application

Work is proceeding on a method of mixing and applying formalin, using equipment already available to most nursery foresters. Trials have been completed of a tractor-drawn trailer fitted with a pump and spray boom for application of formalin solution to seedbeds, with good results.

Weedkiller Spraying Machine

A prototype wheeled pressure sprayer for application of weedkillers to seedbeds and transplant lines was tested in 1951. The machine, which can be propelled by hand or drawn by tractor, has proved capable of controlled application of liquids to seedbeds at volumes from 5 to 100 gallons per acre.

Root pruning

A sledge type of root pruner has been produced in co-operation with Directorate Mechanical Engineer (Scotland). Preliminary trials have shown that on stone-free loamy soils the machine is quite suitable for cutting through one year old root material.

WORK ON PROBLEMS OF AFFORESTATION IN SCOTLAND AND NORTHERN ENGLAND

By J. W. L. ZEHETMAYR
Assistant Silviculturist

Once again a large programme of experimental planting has been undertaken; approximately a quarter of a million plants of some forty species were employed and the area planted exceeded one hundred acres. In order to ensure that adequate supervision and labour can always be available for these new experiments, attention is being devoted to closing and writing-up older experiments which have served their purpose. In some cases the experiments may still be useful for demonstration; but if this is not the case the areas are handed back to the Conservancy. Over one hundred experiments have been closed in this manner during the last two years.

Trial Plantations

The work at Watten (Caithness), Kielder (Northumberland) and Halifax (Yorkshire) is in continuance of that started in previous years, the planting being spread over a number of years so that the risks of encountering an exceptionally good or bad season are minimised. The work at Halifax is once again being undertaken in co-operation with Halifax Corporation, while that in Caithness is on behalf of the Department of Agriculture for Scotland. Table 9 gives details of the trial plantations laid down in the past year.

TRIAL PLANTATIONS LAID DOWN IN 1951-52

Table 9

Forest or Estate	Approx. area acres	Main features of site	Main species
Watten, Caithness	30	Exposed deep poor peat	Shore pine†
Kielder, Northumberland	11	Exposed high lying peat area	Shore pine†
Halifax Corporation Water Catchment Area	14	Variable soils and peat, exposed to industrial fumes.	Japanese larch Lodgepole pine* Sitka spruce
Cleveland, Yorks.	5	Exposed heathland.	Scots pine, Shore pine†, Japanese larch, Sitka spruce Serbian spruce

†=*Pinus contorta* Doug.

*= ,, ,, var. *murrayana* Engel. (=var. *latifolia* S. Watson.)

The inclusion of a plantation based on a matrix of Japanese larch on the best bracken ground at Halifax is a new departure. The object is to obtain at least one mainly deciduous plantation, in an endeavour to escape the effects of the fumes on the foliage during winter, when the severest damage is caused to evergreen conifers. The bulk of the land available is, however, unsuitable for either larches or hardwoods, so that the problem on these sites is to find the most smoke resistant evergreen conifer.

The Cleveland site is on heathland of unusual type with a patchwork of vegetation locally dominated by *Calluna*, *Juncus communis*, *J. squarrosus*, *Nardus*, *Deschampsia flexuosa* and *Empetrum*.

During the year Lewis, Hoy in Orkney, and the Mainland of Shetland were visited in connection with schemes for trial plantations or shelter blocks.

Species and Mixture Trials

Work has continued at Inchnacardoch, Inverness-shire, and Kielder, Northumberland, on the collections of plots of species and mixtures planted with modern methods of ground preparation. In addition part of the large uniform area of deep peat in the trial plantation at Watten, Caithness has been used for a comparison both of various species in mixture with shore pine (*P. contorta*), and also of various methods of arranging the mixture using constant proportions of the two species.

The selection of a number of plots for comparisons of timber volume in the Wykeham experimental reserve in Allerston forest, Yorkshire, marks a new departure in the work on comparison of species. These plots cover not only five species (Scots, Corsican and lodgepole pines, Japanese larch, and Sitka spruce) but also four methods of ground preparation; patch preparation of the pre-ploughing era, shallow ploughing (1928-30) and two intensities of deeper ploughing (1931-39). This series, which will comprise some forty one-tenth or one-twentieth acre plots, should provide comparative data on the long term effects of ploughing as well as close comparisons of the growth of different species. As other experimental areas come to the thinning stage, it is intended to establish similar plots to provide both direct comparisons between these areas and also to give indications of the outturn to be expected from land below the range of quality classes covered by the current yield tables.

Ploughing

A long term ploughing experiment has been planted on poor heathland with a strongly developed podsol, in the Finlay's Seat experimental area at Teindland, Morayshire. The object is to obtain information, over one or more rotations, on the effects of ploughing to various intensities. Six treatments were employed in replicated one-acre plots, these were:—

A. Deep single-furrow ploughing to twelve to sixteen inches depth at five-foot intervals, corresponding with current practice on these heaths, which are generally ploughed by R.L.R., Solotrac or Begg ploughs.

B. Single-furrow "tine" ploughing at five-foot intervals, incorporating subsoiling with a tine to shatter the pan, and the turning out of a furrow some six to eight inches in depth. This plough was the first to be hydraulically mounted, and was developed by the staff of Director (Scotland). It is replacing the deep single-furrow ploughing to a considerable extent on the eastern heaths.

The above two treatments are the only ones for which economic machinery is at present available.

C. Complete shallow ploughing to six to eight inches depth.

D. Complete shallow ploughing to six to eight inches with subsoiling.

These two treatments were carried out with an agricultural plough, the Fisher Humphrey "Bracre". The subsoiling was carried out in advance with a tine from which the mouldboard had been removed, and reached depths of sixteen to twenty inches, possibly the greatest depth to which soil disturbance has been carried on heathlands in this country.

E. Deep complete ploughing to twelve to sixteen inches depth.
F. Deep complete ploughing to twelve to sixteen inches depth,' with subsequent re-cultivation of the surface soil.

These treatments at present would be quite uneconomic, but are the logical extreme treatments for the series, and were carried out with a modified Solotrac plough. Subsequent cultivation with a Howard Rotavator mounted on a Ferguson tractor was most successful, and a very good tilth was produced. This range of treatments is designed to give evidence on the effect of increasing the volume of soil turned over, by ploughing to greater depth or over an increased proportion of the surface area. At the same time it is hoped to evaluate the effect of breaking the pan which lies here at from ten to fifteen inches; thus pan shattering has been achieved by both the deep ploughing and the tine subsoiling.

Two main crops have been planted in these plots, each subplot being large enough to provide for volume measurement of the timber in later years. Scots pine was used as the species native to the site, and secondly, a mixture of true lodgepole pine (*P. contorta* var. *murrayana*) and Japanese larch, which is the crop thought to be the most economic in the light of results from experiments planted over the past twenty-five years. It is hoped that this experiment will be the first of a series of this nature.

Manuring

Work has continued on the placement and differential distribution of phosphate in mixtures of different species, in order to obtain equal early growth, the background to which was outlined in last year's report. At the same time large-scale trials of phosphate are being started on marginal land where phosphate is not essential and would not normally be employed, in order to determine whether in fact its use could be justified by increased production. Small exploratory experiments have also been commenced at Broxa to investigate the effects of lime applied at the time of planting to both hardwoods and conifers.

Relief of Checked Sitka spruce

A number of experiments have been started on relief measures, following surveys of checked spruce areas carried out in recent years at Clashindarroch, Aberdeenshire, and in the Border forests. Treatments under test include draining, mulching, manuring and interplanting with nurse species. Nitrogenous fertilizer applications to semi-checked spruce have produced striking improvements in colour and growth at Broxa, though it is as yet too early to predict how long the response will persist.

Draining

The laying down of the large-scale draining and thinning experiment at Newcastleton, Roxburghshire, an outline of which was given in last year's report, was completed.

Trials of a Rabbit Repellent

Two small experiments were laid down in 1950 to test a proprietary rabbit repellent in areas at Benmore, Argyllshire, and Auchenroddan, Dumfries-shire, where plantations had been continually attacked. Plants of Norway spruce were either dipped before planting or sprayed after planting with various concentrations of the repellent, suitable controls being left untouched. The application proved quite useless and within a few days rabbit damage was evident throughout the plantings, while in a matter of months damage was classed as severe.

Shelterbelts

At Skiall in Caithness an experimental shelterbelt, one and a half chains wide and fifteen chains long, has been planted on a very exposed ridge. Based on experience gained with a twenty-five year old belt at Inchnacardoch it is to serve as a pilot trial for further belts in the far north. The main species used are, in order, an outside line of prostrate mountain pine (*P. mugo.* var. *pumilio*) followed by two lines of the upright form (var. *uncinata*) and three of shore pine (*P. contorta*). A central belt contains seven lines of mixed shore and Scots pines, the latter included as a possible source of small timber, and on the far side the rows of shore and mountain pines are repeated in reverse order.

These nineteen lines of plants, spaced at five feet apart, run the whole length of the belt, but within the lines various spacings of from two to six feet are being compared in order to find out whether or not the early canopy obtained by close spacing is, or is not, offset by later difficulties in tending through plants becoming congested. Complete ploughing was undertaken, using the Fisher Humphrey "Bracre" agricultural plough, and after planting phosphate was applied to all plants. The effect of outside shelter by close mesh wire netting fencing is also being tested as a further aid to early formation of canopy.

THE 1945 BROOM AND PINE NURSING EXPERIMENTS AT COLDHARBOUR, WAREHAM FOREST, DORSET

By M. NIMMO
Assistant Silviculturist

In the 1949 *Annual Report* the Coldharbour nursing experiments were briefly mentioned under the general heading of "Experiments on Lowland Heaths" and it is now thought that they merit a more detailed report.

A month or two before planting, the ground was ploughed with an R.L.R. plough in single furrows at 4½ ft. apart. The four experiments concerned, numbers 70 to 73, are of similar size and layout, each having three replications of the following five treatments:—

A. Pure plots of the nursed species.
B. 2 row—2-row mixture of the nursed species and Scots pine.
C. „ „ „ „ „ „ „ „ „ „ Corsican pine.
D. As "B" but broom sowings on prepared patches between both pines and the nursed species.
E. Nursed species intersown with broom patches.

All the plants and the broom sowings each received an application of phosphate consisting of 2 oz. of bonemeal, with the exception of some control furrows along alternate edges of the plots. The nursed species are Sitka spruce, Norway spruce, Douglas fir and *Tsuga heterophylla*. Owing to shortage of plants the *Tsuga* could not be put out in 1945 but were introduced in 1946.

Unfortunately ground variation has led to somewhat uneven success with the broom sowings, and for this reason means are given separately for results where the broom is vigorous and for the aggregate mean of the broom plots.

This ground variation prevents proper statistical analysis of these experiments, but the differences between growth in the controls and in the phosphate

and broom plots are such as to be beyond doubt. The following table gives the results of assessments made in April, 1952.

HEIGHT AND SHOOT GROWTH OF VARIOUS CONIFERS, GROWN PURE AND IN MIXTURE WITH CONIFER AND BROOM NURSES

Table 10

Expt. No. and Planting Year	Nursed Species	Assessment	Treatments (Measurements in Inches)						
			Control	Pure Plots, plus Phosphate	Scots pine, plus Phosphate	Corsican pine, plus Phosphate	Scots pine and Broom plus Phosphate	Broom, plus Phosphate	
								General Mean	Mean where Broom is vigorous
70.P.45	Sitka Spruce	Height	19.7	34.4	33.1	36.1	52.3	51.9	70.6
		Shoot	0.6	1.6	1.3	1.5	7.5	7.1	11.1
71.P.45	Norway Spruce	Height	12.3	20.8	24.7	20.3	33.6	50.9	55.5
		Shoot	0.5	1.4	1.9	1.4	4.5	11.0	13.3
72.P.46	Tsuga	Height	19.0	24.7	23.2	31.6	28.0	47.2	53.0
		Shoot	1.6	2.0	2.0	3.8	4.3	9.4	10.2
73.P.45	Douglas fir	Height	28.0	42.5	47.6	35.2*	36.0*	63.2	96.7
		Shoot	2.1	3.7	4.0	3.0	2.2	10.8	23.1

*_Note._—These figures are due to exceptional ground variation and die-back of both the broom and the Douglas fir, owing to abnormal soil conditions. The figures for the three replications separately show this well:—

Douglas Fir, mean heights in inches

	Series I	II	III
Phosphate + Corsican pine	40.1	39.6	25.9
Phosphate + Scots pine + broom	31.7	30.6	45.6

From these figures it is clear that, given a successful broom crop, all the four species tried can be established by this method, whereas using phosphate alone, the plants quickly go back into check after the first three years. Considering that it is one year younger than the others, the *Tsuga* is very promising; but Douglas fir shows the greatest vigour at present and the better plots of this latter species will soon be in canopy. It is now intended to try the establishment of sessile and red oaks at Wareham by this method.

Plate IV shows a typical control tree of Sitka spruce on a plot that received no treatment. Plate V illustrates the much better growth obtained with phosphate and broom nurses.

During the next five years or so it will be interesting to watch the results obtained with the pine nurses alone; at the moment they are very poor, but as the pine gains control of the surface vegetation the nursed species is expected to pick up rapidly.

In those plots employing both pine and broom nurses, it can now be seen that the pines benefit from the broom at the expense of the nursed species in all cases except with Sitka spruce. There are also indications that the various species may respond differently when the variety of pine is changed from Scots to Corsican.

It is suggested that these experiments may prove a very useful field for a study of the root interactions of various tree species, and will perhaps yield information useful for the laying down of future mixtures now that the vogue for mono-culture is at last losing ground. The Ecological section is engaged in investigating the causes of the failure of the broom sowings in certain sections

of these experiments. At first sight the trouble appears to be pathological in that the shoots blacken and die back from the tips, many of the seedlings never reaching even a foot high. On the other hand it may well be that the die-back is secondary and that the basic trouble lies in soil variations. The point is well worth investigation because any larger scale work on broom could be spoilt by these patchy results.

INVESTIGATIONS INTO THE REHABILITATION OF DERELICT WOODLANDS

By A. D. MILLER
Assistant Silviculturist

Rehabilitation at Weston Common, Alton Forest, Hampshire

During 1949, it was decided to create at Weston Common, Alton, a demonstration area to show what was considered to be the best method of treating a certain type of derelict woodland. 105.4 acres of this woodland were handed over to the Research Branch during F.Y. 49 and it was decided to use the area as follows:—

	acres
Demonstration Area, Compartments 1, 2, and 3	55.6
Untreated Control. Part of Compartment 5	10.0
Reserved for future experiments, Compartments 4, 6 and part of 5	39.8
	105.4

This area had once carried a mature mixed hardwood crop which was devastated during the ten years following the first world war by a succession of timber merchants who gradually removed all the saleable trees; after this it was entirely neglected for a period of fifteen to twenty years, during which time a dense natural crop of ash and sycamore appeared over most of the area; but what might have been a most promising crop was so severely damaged by rabbits and grey squirrels, while in the young pole stage, that over quite a large part of the area not a single stem could be accepted as part of the new crop.

The first step was to fence the area and destroy the rabbits and grey squirrels, following which the rehabilitation of the Demonstration Area was covered by four main prescriptions; these were:—

(1) To cut those remnants of the old crop which would yield enough produce to pay for their removal and to "ring" those which it would not pay to cut.

(2) In groups where young ash and sycamore poles were too badly damaged to be accepted as part of the new crop they were to be cut back and allowed to coppice. The coppice stools were to be singled later, and tended so as to form a crop.

(3) In groups where damage to the young poles was relatively light, they were to be thinned and accepted as part of the new crop.

(4) Bare areas were to be planted.

During the year the remainder of the old trees were felled and sold, the bare areas in Compartment 1 were planted, and the work of treating the pole crops in Compartments 2 and 3 continued.

All these operations have been carefully costed and the following financial statements drawn up to cover all expenses and receipts since work began there.

EXPENDITURE AND RECEIPTS OF REHABILITATION WORK COMPARTMENTS 1, 2, AND 3, ALTON FOREST

Table 11

Expenditure	£	s.	d.	Receipts from Sales	£	s.	d.
1. Felling, burning and cross cutting	1,213	19	4	1. Cordwood	517	9	3
2. Extraction	538	5	4	2. Minor Produce	86	14	9
3. Thinning poles	234	17	2	3. Timber	4,593	11	6
4. Preparation of produce	602	5	3				
5. Singling coppice stools	7	3	7				
6. Preparation of ground	49	9	7				
7. Planting	50	15	6				
8. Protection	265	9	8				
9 Miscellaneous, including wet time, holidays, and insurance	429	12	4				
Total Expenditure	3,391	17	9				
Balance, being excess of receipts over expenditure	1,805	17	9				
Total	£5,197	15	6	Total Receipts	£5,197	15	6

In addition to the rehabilitation of Compartments 1, 2 and 3, a certain amount of work was done in the other compartments; this consisted chiefly of cutting and extracting the old standards, preparing cordwood, and protection. The following financial statement refers to the whole area of 105.4 acres under the management of the Research Branch.

EXPENDITURE AND RECEIPTS, COMPARTMENTS 1, 2, 3, 4, 5 AND 6, ALTON FOREST

Table 12

Expenditure	£	s.	d.	Receipts from Sales	£	s.	d.
1. Felling, burning and cross cutting	2,071	16	11	1. Cordwood	833	9	3
2. Extraction	1,020	0	5	2. Minor produce	124	0	8
3. Preparation of produce	811	11	4	3. Timber	7,136	17	8
4. Thinning and tending	313	15	5				
5. Preparation of ground and planting	110	8	0				
6. Protection	505	2	0				
7. Miscellaneous, wet time, holidays, insurance	853	14	8				
Total expenditure	5,696	8	9				
Balance, excess of receipts over expenditure	2,407	8	11				
	£8,093	17	8	Total Receipts	£8,093	17	8

Thus up to the present there has been a fair margin of profit on the operation as a whole, but it will be seen that a very high proportion of the receipts came

from the sale of timber; this source of revenue is now at an end but a good deal of money will have to be spent on the area before the crop can be regarded as established, and it is doubtful if the present balance will be sufficient to meet the cost of the necessary work. However it seems likely that the 55.6 acres of the Demonstration Area will be converted into a valuable young forest at little cost.

Conversion of Hazel Coppice to Beech Forest
Gardiner Forest, Dorset and Wiltshire

The establishment of this experiment was described in the *Report on Forest Research* for 1951, and since that date work here has been confined to one weeding and some assessments. The planting in each treatment was done immediately after the hazel coppice had been cut or thinned, so that the transplants have had one growing season relatively free from herbaceous weeds. The hazel stools coppiced vigorously but it was thought that the shade cast by these young shoots was probably not harmful and no weeding was done during the summer.

During the spring of F.Y. 52 the hazel regrowth was lightly cut back; the higher bushes surrounding the groups and strips had not closed-in appreciably and no attention to their crowns was necessary. The work involved in this weeding was carefully timed in each plot, and the number of "man-hours" involved in each treatment is shown in the table below; these times have been converted to costs at the rate of 2/5d. per hour, the current rate for a Grade II forest worker.

COSTS PER ACRE OF WEEDING ONE-YEAR-OLD HAZEL COPPICE SHOOTS, MEAN VALUES FROM SIX REPLICATIONS OF EACH TREATMENT

Table 13

Treatment (1)	Type of Weeding (2)	Man-hours (3)	Cost (4)
			£ s. d.
A. Large Groups	Cutting back all regrowth which was interfering with beech plants	1½	0 3 8
B. Small Groups	Cutting all regrowth within each group	2	0 4 10
C. Strips	Cutting all regrowth within the strips....	6¾	0 16 4
D. Thinning	Cutting the regrowth where necessary to free beech plants	6⅔	0 16 2
E. Clearance	Line weeding, leaving regrowth not closer than 1½-2 feet to a beech plant so as to provide shelter	14	1 13 10

Assessments during the first season's growth

(*a*) *Survival.* The one-plus-one beech transplants were put in between 24th January, and 4th March, 1951, generally under very moist conditions, and up to the beginning of June there seemed to be almost 100% survival and an average shoot growth of one to three inches.

However there was a very little rain during the end of June and July and the soil tended to crack, particularly around the cuts made by the planting spades, allowing air to penetrate to some of the roots. Early in August many of the plants seemed to be affected by drought conditions, their current year's growth withered and about 30 per cent looked as though they might die.

The wetter months of August and September, brought about a distinct improvement in the appearance of the plants, new growth was made and some of the apparently dead trees produced new buds and leaves. Assessments were made of survival during September, and the percentage of deaths is shown in Table 14 below.

SURVIVAL OF BEECH PLANTED ON OLD HAZEL COPPICE SITE

Table 14

Treatment	Number of trees assessed	% Sample	% of deaths
A. Large Groups	1,555	100	5.9
B. Small Groups	1,680	100	3.1
C. Strips	1,517	50	2.9
D. Thinning	1,456	17	3.4
E. Clearance	1,441	17	9.7

(*b*) *Height.* At the end of the first growing season the height of a number of sample plants in each plot was measured; these heights are not significant in themselves but will provide the basis for future comparison of growth rates in the different treatments. There was little variation in these initial heights, the smallest being 9.0 inches and the largest 10.4 inches.

(*c*) *Light intensity.* In late September, 1951, but while the hazel coppice was still in leaf, an assessment was made of the light intensity reaching the beech in each treatment compared with full daylight in an open area. Mean values of five readings for each treatment are shown in Table 15 below.

PERCENTAGE OF DAYLIGHT REACHING BEECH PLANTS ON OLD HAZEL COPPICE SITE

Table 15

Treatment	% of full daylight
A. Large Groups	66
B. Small Groups	59
C. Strips	72
D. Thinning	48
E. Clearance	100
In adjacent untouched coppice	5—20

Evidence from earlier work shows that the amount of light reaching the beech in all treatments is quite sufficient to permit vigorous growth.

Rehabilitation of a Felled Hardwood Site at Well Covert, Haldon Forest, Devon

Information provided by the recent Census of Woodlands has shown that in the South of England the areas described as Scrub, Devastated, and Felled Woodlands account for about two thirds of the total of derelict woodlands. Current figures also suggest that at the present rate of planting it may take as long as sixty years to bring all these old woodlands into a productive state unless speedier methods of rehabilitation are found.

An unknown but probably very large number of acres of these derelict woodlands carry natural regeneration and woody regrowth which contains at least some potentially valuable stems which would be cut back in the normal processes of clearing and replanting. If use can be made of such growth, which is frequently between five to twenty years old, it would be a mistake to cut it; this experiment was designed to test whether by departing a little from the normal practices in replanting, the rate of dealing with such old woodlands could be speeded up and also make a saving of labour and money.

There are three aspects of the methods which have been selected for comparison with normal procedure; they are:—

(1) *Silviculture.* We wish to know whether it is possible to produce a valuable final crop of timber species by accepting and tending the relatively small number of valuable young stems which are frequently scattered through the apparently worthless thickets of birch and weed trees; and taking into account the probability of damage to some of the selected stems to find what is the minimum number of young trees necessary to produce a final crop.

(2) *Protection.* Most old hardwood sites are infested with rabbits, and it is essential to give the new crop adequate protection. Where a small number of selected stems are to be tended amongst a thicket of weed species it would be difficult and expensive to eliminate rabbits, and it was decided to test whether it would be possible and convenient to give adequate protection by sleeve netting each selected stem. The usual rabbit-proof fence round the area might then be omitted. There are several objections to the widespread use of such a method but there might be occasions when, if it proved successful, it could be recommended.

(3) *Costs.* There are two sides to the question of the costs of treating derelict woodlands.

(*a*) The cost of labour is a direct measure of the effort spent on rehabilitation; if some methods are found to be cheaper than others yet equally satisfactory, their use would allow a larger area to be treated within a given time.

(*b*) Many derelict woodlands are in private ownership and the high cost of normal methods of clearing and replanting often deters the owners. If some cheaper method is found to be silviculturally satisfactory more private owners might feel able to rehabilitate their own woods.

It is realized that the crops produced by tending from 100 to 200 valuable stems per acre amongst a less valuable matrix will probably be unsatisfactory in some respects, pruning may be necessary to produce a useful length of clean bole and intermediate yields will be very low. Nevertheless it may be possible to take advantage of the fact that the crop is several years old to hasten the time when it will produce saw timber, and by doing a minimum of tending and cleaning it may be possible to produce a more or less fully stocked final crop of saw timber on a larger number of acres than would have been possible had normal practice been followed.

The Experimental Site

A suitable area was found at Well Covert, Haldon Forest, Devonshire, where a broadleaved woodland had been clear cut in the early part of the recent war. This wood lies in a valley, on the Culm Measures, at an average elevation of 250 feet, and has a clay-loam soil. Of crescent-shaped outline, it is about one mile long, with an average width of eight chains, and is surrounded by agricultural land. At the time of acquisition it carried a rabbit infested thicket of coppice growth of ash, sycamore, oak and beech, together with natural seedlings of oak, beech, ash, sycamore and gean, scattered irregularly over the whole area. Birch of all ages from one to ten years was found everywhere, and

in places had formed dense groups. Hazel, rowan, sallow, wych elm, elder, and gorse were the chief weed trees, while abundant bramble and briar sometimes shoulder-high made working conditions difficult.

The whole acquisition covered about sixty-four acres, of which some twenty-eight acres has been devoted to this experiment, and has been split up into plots of about three acres for each treatment. A detailed description of the natural growth on each plot was written before work began.

Treatments

It was decided to compare the crops produced and the costs incurred by the following treatments:—

1. Conserving all useful and valuable stems which showed prospect of getting into the canopy, tending where necessary, pruning the crowns to maintain a central axis, and pruning the stems to half total height.

No planting was done. Because the thicket was very dense, racks were cut every 100 feet to give access, otherwise the regrowth was cut only where necessary to relieve selected stems.

This treatment was split for method of protection against rabbits:—

(*a*) Each selected stem was protected individually by a sleeve of wire netting; a rabbit-proof fence was not put around the plot, to which rabbits had free access.

(*b*) The plot was fenced around and rabbits destroyed within the fence.

2. As treatment 1 above, but enriching the existing growth with beech transplants large enough to be free from weed competition, (not including weed trees). Sufficient big transplants were put in to ensure that the spacing of selected stems was never more than eighteen by eighteen feet, and it was hoped that this would give a fully stocked final crop.

This treatment was also split for method of rabbit protection.

(*a*) Sleeve netting selected stems.

(*b*) Fenced and rabbits destroyed.

3. Applying what was considered to be the most suitable form of conventional re-afforestation, thinning the thicket very heavily so as to leave only a very sparse and open canopy under which one-plus-one beech transplants were put in at five foot by five foot spacing. The new crop is to consist of pure beech and the light overwood will be removed when the interests of the planted beech demand it. The area was fenced and rabbits destroyed.

4. Control. No silvicultural treatment at all. This was also split for rabbit protection:—

(*a*) No protection. Rabbits allowed free access to the plot.

(*b*) Fenced around and rabbits destroyed inside the fence.

Laying out the Experiment

These treatments were carried out between January—March, 1952. Because of the very dense undergrowth over this area it was necessary to cut inspection racks, spaced at 100 feet and roughly parallel, before the plots could be laid out or any other work be started; the cost of these racks varied considerably from place to place but the average cost over the whole experimental area was £1 per acre.

Preparation of Ground

The initial work of cleaning, or preparing the ground, in treatments 1 and 2 involved locating and then freeing the crowns of promising young ash, sycamore, beech, oak, and gean both of seedling and coppice origin. This work, and the more thorough cleaning and burning in treatment 3, was carefully timed, and

the number of man-hours spent in each plot is shown below; these times have been converted to costs at the rate of 2/6d. per hour.

COSTS OF INITIAL CLEANING, OR PREPARATION OF GROUND AT WELL COVERT, HALDON FOREST

Table 16

Treatment	Area in acres	Man-hours	Man-hours per acre	Cost per acre
				£ s. d.
1. (*a*)	3.06	81	27	3 8 0
(*b*)	5.33	231	44	5 10 0
2. (*a*)	3.20	108	34	4 5 0
(*b*)	3.40	86	25	3 3 0
3.	3.02	305	101	12 13 0
4. Control	—	—	—	—

There were a number of groups where most of the canopy had been made up of the more vigorous weed trees, and when these were removed to relieve smaller oak, ash, or sycamore the more valuable species were found to be rather drawn up and spindly, and it was thought that they might suffer from the sudden exposure; it was, however, difficult to see how this could be avoided.

Pruning the selected trees in plots, 1(*a*), 1(*b*), 2(*a*), and 2(*b*) cost an average of 10/- per acre.

Planting

The large beech transplants for use in treatments 2(*a*) and 2(*b*) were bought from a private nursery at a cost of £4 per 100, and were about 2½ feet high. Slightly taller plants of from four to five feet would have been preferred, but were not available. The one-plus-one beech transplants used in treatment 3 were from twelve to eighteen inches high and their cost has been taken as £6 per 1000.

In plots 2(*a*) and 2(*b*) a large beech was carefully pit planted wherever natural valuable stems were spaced wider than eighteen feet apart. The costs of plants and planting are shown below.

COSTS OF PLANTS AND PLANTING AT WELL COVERT, HALDON FOREST

Table 17

Plot	Area	No. of trees planted	No. of selected stems per acre	Man-hours planting	Man-hours planting per acre	Labour cost of planting	Cost of trees	Total cost of planting	Cost per acre
						£ s. d.	£ s. d.	£ s. d.	£ s. d.
1. (*a*)	—	—	84	—	—	—	—	—	—
(*b*)	—	—	92	—	—	—	—	—	—
2. (*a*)	3.20	137	116	21	7	2 13 0	6 3 0	8 16 0	2 15 0
(*b*)	3.40	151	110	17	5	2 3 0	6 16 0	8 19 0	2 13 0
3.	4.53	8,300	—	152	34	18 13 0	50 6 0	68 19 0	15 4 0
4. Control	—	—	—	—	—	—	—	—	—

Rabbit Protection

Fencing. That part of the experimental area enclosed by rabbit proof fencing was only 16.42 acres and an estimate of the cost per acre of fencing such a small

area would be unduly high; therefore the actual costs per chain were determined, and the cost per acre calculated as though the whole 64 acres of woodland had been enclosed in a single rabbit proof fence. The cost of fencing was worked out as follows:—

Cost of One Chain of Rabbit Proof Fence

	£	s.	d.
Wire netting	1	11	0
8 gauge and tying wire	0	2	0
Stakes	0	12	0
Strainers (1 at 10/- per 4 chains)	0	2	6
Total cost of materials	£2	7	6
Labour	0	19	0
Total cost per chain	£3	6	6

On this basis the cost of fencing the whole area would have been at the rate of £10 18s. 0d. per acre. This rate is of course based on the actual long-and-narrow shape of the whole wood; but as so many such woodlands have a similar outline it may be accepted as a fair average. Had the wood been square, the fencing cost would have been only £5 10s. per acre.

Sleeve netting. The costs of sleeve netting were assessed in the following way. Using 18 inches per sleeve of 42 inch wide by $1\frac{1}{4}$ inch mesh by 18 gauge netting, one roll of 50 yards gives 100 sleeves. Thus the cost of the material in each sleeve is $8\frac{1}{2}$d., and this together with the labour costs of cutting and fixing the sleeves cost 1s. 2d. each or £5 1s. 0d. per acre in plot 1(*a*) and £6 16s. 0d. per acre in 2(*a*), the difference being due to the larger number of sleeves fixed in plot 2(*a*).

Warrener. A warrener was employed to reduce the number of rabbits in those plots which were within the rabbit fence, that is in all plots except 1(*a*), 2(*a*), and 4(*a*). He was unable to kill all the rabbits in those areas where the growth was not cleared, and further attention to the rabbits will be necessary. The cost of this preliminary work in killing the majority of rabbits through the remains of the thicket cost an average of 17/- per acre, while that of exterminating them in the clear-cut plot (3) cost 7/- per acre. Initial costs involved in these different ways of tackling this area are shown below.

SUMMARY OF THE COSTS PER ACRE OF INITIAL OPERATIONS, WELL COVERT, HALDON FOREST

Table 18

	1(*a*)			1(*b*)			2(*a*)			2(*b*)			3			4(*a*)		4(*b*)		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	s.	d.	£	s.	d.
Cutting racks	1	10	0	0	13	0	1	5	0	1	10	0	0	13	0	8	0	2	0	0
Cleaning	3	8	0	5	10	0	4	5	0	3	3	0	12	13	0					
Pruning	0	13	0	0	10	0	0	10	0	0	10	0								
Planting							2	15	0	2	13	0	15	4	0					
Fencing or sleeving	5	1	0	10	18	0	6	16	0	10	18	0	10	18	0			10	18	0
Warrener				0	10	0				1	1	0	0	7	0			1	1	0
Total	10	12	0	18	1	0	15	11	0	19	15	0	39	15	0	8	0	13	19	0

Thus it will be seen that the costs per acre of the treatments, not counting the controls 4(*a*) and 4(*b*), vary from £10 12s. 0d., in the case of 1(*a*) to £39 15s. 0d. in the case of 3.

These are initial costs only, and the picture may be changed by the time the crops are established, it is of course the total costs of establishment which will be significant. Moreover at this stage it would be wrong to attach too much importance to the question of expenditure, and the first thing is to see whether the methods are silviculturally sound. It is when there is a choice of methods which are known to produce the type of crop which is wanted that the matter of costs should be closely considered, and even then economic factors should be kept in their proper perspective and not allowed to outweigh all other relevant considerations. However, when more than one treatment is suitable the selection of method may be influenced by the costs expected to be involved in each, and it is important that reasonably reliable figures should be available.

EXPERIMENTAL WORK ON ESTABLISHING HARDWOODS IN SCOTLAND

By R. FAULKNER
Assistant Silviculturist

Because of the increase in the number of properties acquired in south Scotland suitable for replanting with hardwood species, and the overall low acreage of hardwoods within the area as revealed by the Census of Woodlands Report, more research work on the problems of re-afforestation and management of hardwood areas is to be undertaken.

Initial work will be concentrated on the selection of species for specific site types, methods of mixing species, and the raising of hardwoods using conifers as "catch crops" or "nurse" species. In addition provenance and individual tree type experiments will be started. Pedunculate and sessile oak, beech, sycamore, wych elm, ash, lime, and gean are the main species to be used in the experiments, which will be concentrated on suitable areas in Perthshire and to the south.

Preparatory work on raising suitable stocks of plants in the nursery was started during the year, and supplies of gean, sycamore, and wych elm seed have been collected from suitable trees, and sown.

At Brownmoor Forest, Dumfries-shire, a sixteen acre unit of birch, sycamore and thorn scrub has been taken over and partially cleared. Trial plots of gean, sycamore, beech and pedunculate oak have been planted on the cleared portions along with a beech provenance trial (Brownmoor Forest, Expt. No. 1) containing seven British provenances.

CHEMICAL CONTROL OF WOODY WEED GROWTH

By G. D. HOLMES
Assistant Silviculturist

The investigation of methods of eradicating undesirable woody weed species was extended to include trials on sycamore coppice and bramble (*Rubus*

fruticosus), both of which can prove troublesome weeds in newly planted areas in some localities. These trials have not yet run their full course and the conclusions out-lined below are tentative.

Bramble

The most satisfactory treatment has been mid-summer foliage spraying with a 2:1 mixture of butyl 2, 4-D and butyl 2, 4, 5-T at 0.5% in oil emulsion at 50 gallons solution per acre. This appears to have caused a complete kill with no appearance of regeneration within nine months after treatment. Ammonium sulphamate applied in solution at 100 lb. per acre has also given a good kill. Sodium 2, 4-D or potassium 2, 4, 5-T caused an initial kill of foliage and young shoots, but growth is now showing signs of recovery.

Sycamore

Spray applications were made in midsummer to young regrowth on stumps cut one year previously. Sodium 2, 4-D and potassium 2, 4, 5-T gave a good initial foliage kill, but all stools showed a general recovery by the end of the season. The mixture of butyl 2, 4-D and butyl 2, 4, 5-T applied at 0.5% at 50 gallons per acre has apparently killed all aerial growth, and no regeneration has appeared within nine months of treatment.

These results appear to confirm the conclusion made from trials on other species, notably ling (*Calluna vulgaris*) and hazel, that the ester formulations of 2, 4-D and 2, 4, 5-T are more effective against woody species than the water soluble sodium, potassium or tri-ethanolamine salts.

The trial plots on ling, described in the last report, were planted up with Corsican pine and Sitka spruce in 1951, to test the effect of chemical eradication of ling on the growth of trees subsequently planted.

CHEMICAL KILLING OF TREES TO FACILITATE BARK REMOVAL

By G. D. HOLMES
Assistant Silviculturist

A series of experiments were started to examine methods of killing standing trees prior to felling, to facilitate bark removal. Recent work on several species in the United States, has shown that application of toxic solutions to girdles cut at the base of the stem can effectively kill the tree and loosen the bark. The advantage of such treatment is to enable easy and cheap bark removal, if necessary outside the normal "sap peeling" season. Killed trees also dry out rapidly, thereby reducing weight and handling costs.

Application of sodium arsenite or ammonium sulphamate solution to trees of Corsican pine, Japanese larch, and Sitka spruce in spring 1951, have shown promising results. The treated trees ranged from three to seven inches breast-height quarter-girth, and were due to be felled in normal thinning operations in winter, 1951. Several methods of applying the poisons were tested, and the most generally successful was to completely remove the bark down to the sapwood

in a ring six to eight inches wide around the stem, followed by application of the solution to the exposed sapwood by means of a paintbrush. Application of arsenic or sulphamate salt, dry or in solution, to boreholes or cups cut in the base of the trees, was less successful.

A 40 per cent solution of sodium arsenite, applied to a complete girdle as described, killed standing trees of Sitka spruce and Japanese larch within a few weeks of treatment. Trees girdled at the same time, without chemical treatment, had apparently normal, healthy crowns one year after treatment. Corsican pine has proved less easy to kill, and trees treated with arsenic were not completely dead until six months after application. The bark has been satisfactorily loosened on all trees which succumbed rapidly to chemical treatment. Trees treated with ammonium sulphamate were killed more slowly and bark was incompletely loosened.

These trials have shown that the rapid kill necessary for efficient bark loosening is best ensured by applying the poison when the sap is in full flow in the spring. It is important that the solution be applied around the whole circumference of the treated portion of the stem. Little lateral movement of the poison takes place, and if the application is incomplete live strips of rind remain firmly attached to the wood above the untreated portion. Thus application of poison to boreholes at the stem base, kills only strips of rind immediately above each borehole.

Trees killed with arsenic showed very little penetration of the toxin below the point of application, and there has been no indication of the spread of the poisoning effect to adjacent trees. The trials are still in progress and the comparative peeling costs for treated and untreated trees are to be determined, in addition to assessment of weight-loss due to timber drying on the stump.

PROVENANCE STUDIES

By M. V. EDWARDS, *Silviculturist*
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European Larch

(*a*) International Larch Provenance Experiments, Planted 1946

In 1944, the International Union of Forest Research Organisations distributed a comprehensive range of larch seed from various regions of Europe for the purpose of establishing provenance trials under the supervision of the participating organisations. The trials were laid down simultaneously in Canada, Denmark, England, Finland, France, Germany, Italy, Norway, Sweden and Slovakia. From time to time reports on the progress of the trials are submitted to the Union for collation by the Section Leader (Provenance), Dr. Syrach Larsen. The trial was planted at five centres in England and one in Scotland.

Geographic Range of the Provenances

The trial comprises a total of forty-four different seed lots collected from the main regions of the natural distribution of European larch, as well as from regions outside where it has become established as a successful exotic forest

species (e.g. British Isles, German coastal plain). Included in the collection are seventeen lots from the Austrian Alps; three from the Italian and two from the Swiss Alps; two from the foothills of the High Tatra Mountains of Slovakia; four from Moravia, including two from the Sudeten Mountains; seven from the coastal plain and western lowlands of Germany and Poland; five from England and Wales, and two Scottish seed lots, one from Scotland and one from Sweden. One lot of Siberian larch (*L. sibirica*) and one of Japanese larch were also included.

One seed lot, (Mark A. 14, Waldstein, Austrian Alps), of which large supplies were available, was replicated seven or eight times at each centre, and will be used as a basis of comparison with the others. Of the other origins, however, the number of replications which could be adopted was fewer and in many cases only single plots could be planted.

Centres at which the Provenances have been Planted

In England the trials were laid down in 1946, by the Research Branch, simultaneously at the five forests of Savernake in Wiltshire, Haugh and Mortimer in Herefordshire, Wyre in Worcestershire and Walcot in Shropshire on felled woodland sites in all cases. The following year they were also laid down on old pasture land at Drummond Hill Forest, in Perthshire, having been held over on account of severe weather.

The sites selected are all fairly uniform as regards topography. At Drummond Hill the plots are at an elevation of 840—1,000 feet, at Walcot 850—950 feet, at Mortimer 800 feet, at Haugh 350—475 feet, at Savernake 450—500 feet and at Wyre 300 feet. The plots at Drummond Hill and at Haugh are on a moderately steep slope, and are fully exposed to the prevailing wind, whereas at the other sites they are on slight to gentle slopes and receive a moderate degree of shelter from the shape of the topography. The aspect is variable.

The full range of forty-four origins was planted at Savernake Forest, but at the other centres only part of the range could be planted, owing to the smallness of the quantities of seed supplied of some of the origins. Care was taken, however, to distribute the various origins among the different centres so as to achieve the maximum effect for the purposes of forming comparisons. Furthermore, at each centre the seven or eight plots of the standard race were distributed over the area in such a manner that they could be compared with all the non-standard races. The total numbers of origins planted at each centre are as follows: Savernake—44; Walcot—30; Haugh—16; Mortimer—16; Wyre—14; Drummond Hill—20 (including one extra lot of Scottish seed).

A preliminary account of the five English experiments incorporating the growth data collected up to the end of the third growing season appeared in the *Report on Forest Research* for 1950. A report on the Drummond Hill experiment was published in the *Report on Forest Research* for 1951.

The plants were put out at the five centres in England as one-plus-one transplants, with the exception of the five home lots which were one-plus-two. At Drummond Hill, however, the plants of the Union collection were one-plus-one-plus-one, and the two Scottish lots one-plus-two-plus-one and two-plus-one transplants. The layout was in randomised plots, and at Drummond Hill the plots were arranged in nine blocks in the form of a latin square.

Assessment

Annual assessments of height and shoot growth up to 1950, and periodic assessment of diameter at mid-height, deaths and phenological characters

(i.e. flushing and leaf-fall) have been carried out in all the English experiments. The growth data presented in this report (Tables 19 and 20) were collected in The growth data presented in this report (Tables 19 and 20) was collected in the autumn of 1950 when the trial was at the end of its fifth season. Phenological data collected in 1949 and 1950 are also given in a summarised from (Table 21).

Losses of Plants

The majority of the plots at Savernake suffered heavy losses from drought and late spring frosts in the first year, but at the other centres planting losses were not abnormally high. Siberian larch, which was planted at Savernake, Mortimer and Walcot, suffered losses amounting to 89, 86 and 14 per cent respectively in the first year, and by 1951 had failed entirely, apart from one or two plants at Walcot. This species appears unsuited to the climate of this country since its early flushing habit exposes it to annual frost injury.

Pests and Diseases

Rabbit damage has not been of serious importance, except at Wyre where both rabbits and deer caused severe damage and losses in some parts of the area during the first few years. There has been a steady increase in the extent and severity of the damage caused by the shoot-borer (*Argyresthia*) and leaf-miner (*Coleophora*), particularly in the plots at Walcot and Mortimer. It is intended in the coming year to assess differential injury at the centres where it is most apparent. Considerable loss of foliage has been caused by periodic infestations of *Adelges*, while the Pine Weevil (*Hylobius*) gave some trouble in the early stages at some centres following the felling of the old coniferous crop. Insect injury is generally more severe at Walcot and Mortimer, where the plots are situated in close proximity to older conifer stands. The effect of these injuries on the development of the various races will be studied.

Rates of Growth

Very wide differences in growth rates between many of the lots are evident, as could be expected with such a wide range of origins. Broadly the different geographical groupings are characterised by different degrees of vigour. Most outstanding of all are the group of low altitude origins from the coastal plain of Germany and Poland and the West German Lowlands (Mark F), the group of four medium altitude origins from Moravia, including two from the Sudeten Mountains (Mark I), and the group of two lots from Slovakia at medium altitudes in the High Tatra Mountains (Mark K). With only one or two exceptions races from these sources of origin are to be found among the nine most vigorous races at every centre. The best are Mark F.29 (Harbke, Brunswick), F.31 (Neumunster, Schleswig Holstein), F.32 (Proskau, Upper Silesia), I.45 (Hrottowitz), I.49 (Parchowitz) and K.52 (Murau, Liptovsky Hradok) which have all grown at a faster rate than Japanese larch.

The alpine group of origins from Austria (Mark A), Italy (Mark C) and Switzerland (Mark D) compare very unfavourably with the foregoing in rate of growth. At every centre the alpine origins are, with few exceptions, among the eight slowest growing races. Those which are conspicuously poor at more than one centre are: Mark C.25 (Val Venosta, Italy), D.26 (Lotschenthal, Switzerland), D.27 (Untervaz, Switzerland), A.1 (Bluhnbach, Austria), A.3 (Hollenburg, Austria), A.7 (Landeck, Austria), A.8 (Murau-Murau, Austria), A.13 (Steinach-Muhlbach, Austria) and B.15 (Michael, Austria). Races which could only be tried at one centre but are also among the slowest growing are: Mark

C.23 (Lago, Italy), A.10 (Pitztal, Austria), A.11 (Ried-Tosens, Austria), B.16 (Murau-Paul, Austria), B.17 (Ried-Pfunds, Austria) and B.18 (Steinach-Gries, Austria).

The two Scottish larches of the Union collection, as well as the additional race of Lethen origin planted at Drummond Hill, have proved, on the whole, disappointing. At the English centres neither the Aldroughty nor the Swedish origin figures among the most vigorous in growth rate at any centre, while at Drummond Hill the Lethen race is one of the least vigorous and also suffered the highest initial losses, averaging 24 per cent. At most centres the Scottish races appear among the poorest growth classes. It is worth noting that the Aldroughty race, though one of the slowest at the English centres, is one of the fastest at the Drummond Hill site.

The five English and Welsh origins are not outstanding in any way and, in general, occupy an intermediate position as regards vigour. Of these, Race 43/13G from North-west England has done the best, being among the nine most vigorous at three out of five centres. None of this group was planted at Drummond Hill.

Very good results are shown by the lot of Japanese larch from Denmark (Mark E.28) which, except at Savernake, is among the eight fastest growing at every centre.

Rate of Growth in Relation to Altitude of Origin

Some very interesting comparisons can be made within the group of Austrian alpine origins, which cover a range of altitudes from 1,640 to 6,560 feet. In Table I these are grouped in five altitude ranges for the purpose of comparison. From this data it can be seen that the general tendency is for the lower altitude origins to grow at a faster rate than those from the higher altitudes. Races which are particularly vigorous among the alpine lots are A.6. (Lamerau, 2,300 feet) A.14 (the standard race Waldstein, 1,640-1,970 feet) and A.5 (Krumbach, 1,970 feet). The Lamerau race, Mark A.6, in particular has grown remarkably well, being among the seven most vigorous at three out of the four centres at which it was planted. The poorest races in this group are from the the higher altitudes and are A.7 (Landeck, 2,300-2,630 feet), A.10 (Pitztal, 2,950-4,100 feet) A.11 (Ried-Tosens, 3,120-3,780 feet) and A.13 (Steinach-Muhlbach, 2,950 feet). The members of this group exhibit a marked diversity in their rates of growth.

In the case of the other geographic groups, which mostly consist of only one or two lots, the relationship between altitude and rate of growth does not apply.

Site Quality

Differences in site quality are reflected in the growth rate of the standard race, Mark A.14, Waldstein which, being replicated seven or eight times at each centre, can be taken as a fair criterion. Taking the 1950 assessment as a basis Savernake (Race A.14, mean height 107.6 inches) is the best site followed by Walcot (101.5 inches), Haugh (99.3 inches), Mortimer (96.3 inches), with Wyre (84.3 inches) and Drummond Hill (end of 1951—84.2 inches) the poorest. It is thought, however, that when the tree crops have overcome the competitive effect of different types and densities of vegetation cover this order might conceivably change at some later date. Some suppression of the vegetation is beginning to take place in the more vigorous plots.

Table 19 MEAN HEIGHT GROWTH OF LARCHES OF VARIOUS PROVENANCES, BY GEOGRAPHIC REGIONS AT END OF FIFTH SEASON

Mark	Geographic Region	Altitude feet	No. of Different origins	Mean Height (Inches) 1950					
				Savernake	Haugh	Wyre	Walcot	Mortimer	Drummond Hill (P.47 Assessed 1951)
A and B	Austrian Alps	1,640-1,970	3	98.8(3)	90.6(2)	85.0(2)	97.6(3)	96.3(1)	84.9(2)
	,, ,, ...	2,300-2,630	3	97.6(3)	102.0(1)	—	95.8(3)	95.0(1)	81.1(2)
	,, ,, ...	2,800-3,280	5	93.7(5)	91.2(2)	74.5(1)	87.6(4)	82.1(2)	80.2(1)
	,, ,, ...	3,280-4,100	3	85.9(3)	—	—	—	—	—
	,, ,, ...	5,250-6,560	3	85.1(3)	—	66.7(1)	92.6(1)	—	75.4(1)
C	Italian Alps	3,300-4,300	3	85.7(3)	—	61.8(1)	89.7(1)	—	—
D	Swiss Alps	1,400-4,920	2	87.6(2)	73.0(1)	70.4(1)	80.4(2)	87.6(1)	72.9(2)
K	Slovakia, Tatra Mountains	2,630-3,430	2	116.3(2)	96.0(1)	98.4(1)	104.4(1)	—	—
I	Moravia, Sudeten Mountains	2,300	2	112.8(2)	—	—	—	100.4(1)	—
,,	,, Parchowitz and Hrottowitz	1,150-1,350	2	127.6(2)	—	—	113.0(2)	—	79.4(1)
F	Coastal Plain of Germany and Poland	80-330	5	108.4(5)	88.5(3)	87.9(3)	104.7(5)	96.5(3)	84.1(5)
,,	W. Germany, Odenwald	655-985	1	113.6(1)	79.0(1)	—	105.9(1)	—	82.8(1)
,,	Upper Silesia	330-655	1	126.6(1)	113.0(1)	—	95.8(1)	104.5(1)	83.6(1)
E	Denmark (Japanese Larch)		1	111.4(1)	89.0(1)	96.6(1)	108.8(1)	97.3(1)	90.4(1)
L	Scottish Larch from Sweden		1	94.4(1)	—	—	86.6(1)	86.3(1)	73.4(1)
	Scotland, Aldroughty Estate, Morayshire	160	1	107.1(1)	77.1(1)	63.7(1)	92.3(1)	86.0(1)	88.2(1)
	,, Lethen Estate, Nairnshire	300-500	1	—	—	—	—	—	70.0(1)
	England, N.W. and N.E.		4	98.6(4)	80.2(2)	81.2(2)	96.7(2)	89.6(2)	—
	Wales, Brechfa		1	96.1(1)	—	—	—	—	—

Note: No. of Lots Representing each Geographic Region appears in brackets under each Forest

MEAN HEIGHTS AND LOSSES PER CENT OF LARCHES OF VARIOUS PROVENANCES, AT THE END OF THE FIFTH SEASON (1950)

Table 20

Mark	Origin of Seed	Altitude (feet)	Savernake		Walcot		Haugh		Mortimer		Wyre		Drummond Hill (P.47. Assessed 1951)	
			Mean Ht. (in.)	Total losses %	Mean Ht. (in.)	Total losses %	Mean Ht. (in.)	Total losses %	Mean Ht. (in.)	Total losses %	Mean Ht. (in.)	Total losses %	Mean Ht. (in.)	Total losses %
A.1	Alps, Austrian, Bluhnbach	1,970	91.2	43	101.0	1	82.0	7						
A.3	,, ,, Hollenburg	2,950	84.7	81	84.3	1								
A.4	,, ,, Innsbruck	2,800-3,120	109.3	24	98.5	1					74.5	9		
A.5	,, ,, Krumbach	1,970	97.7	39	90.2	1					85.8	11	85.7	5
A.6	,, ,, Lamerau	2,300	107.5	26	108.8	5	102.0	3	95.0	4				
A.7	,, ,, Landeck	2,300-2,630	88.0	60	77.7	7							82.2	12
A.8	,, ,, Murau-Murau	2,950-3,280	96.0	48	81.3	1	83.0	8	72.6	4			80.2	14
A.9	,, ,, Obervellach	3,280-3,940	92.4	38										
A.10	,, ,, Pitztal	2,950-4,100	74.1	58										
A.11	,, ,, Ried-Tosens	3,120-3,780	91.2	51										
A.12	,, ,, Schottwien-Wartenstein	2,630	97.3	10	101.0	2							80.0	11
A.13	,, ,, Steinach-Mulbach	2,950	96.6	58	86.2	3	82.5	6	91.6	2				
A.14	,, ,, Waldstein (*Standard Race*)	1,640-1,970	107.6	17	101.5	4	99.3	8	96.3	6	84.3	15	84.2	10
B.15	,, ,, Michael....	5,250-5,900	80.6	47	92.6	Nil					66.7	9		
B.16	,, ,, Murau-Paal	2,950-3,280	81.9	26										
B.17	,, ,, Ried-Pfunds	5,900-6,560	100.0	14										
B.18	,, ,, Steinach-Gries	5,900-6,560	74.6	26									75.4	14
C.23	,, Italian, Lago	3,280	87.3	49										
C.24	,, ,, Fendo	3,940-4,270	102.0	13										
C.25	,, ,, Val Vanosta		67.9	40	89.7	2					61.8	12		

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D.26	Alps, Swiss, Lotschenthal, Wallis	4,920	72.4	25	68.3	1							63.7	3
D.27	,, ,, Graubunden, Untervaz	1,410-2,130	102.9	55	92.5	1	73.0	15	87.6	3	70.4	7	82.1	6
E.28	Japanese Larch from Denmark		111.4	18	108.8	3	89.0	6	97.3	5	96.6	8	90.4	4
F.29	German and Polish Lowlands — Harbke, Brunswick	500	117.1	29	116.5	5	89.1	10	99.4	4	95.0	61	83.6	14
F.30	German and Polish Lowlands — Neckargemund, Baden	655-985	113.6	40	105.9	2	79.0	21					82.8	18
F.31	,, ,, Neumunster Schleswig-Holstein	98-230	105.7	42	97.9	2	90.7	10	99.7	3	84.7	25	87.6	6
F.32	,, ,, Proskau, Upper Silesia	330-655	126.6	22	95.8	2	113.0	17	104.5	4			83.6	14
F.34	,, ,, Schlobitten, East Prussia	197-230	101.9	46	105.4	4							83.6	8
F.35	,, ,, Sobbowitz, Danzig	197-328	105.2	31	107.4	2							85.1	6
F.36	,, ,, Stolp, Pomerania	82-98	112.1	45	96.1	2	85.6	6	90.3	5	83.9	9	80.8	16
G.37	Siberian Larch from Punkaharju, Finland				7.7	81			2.5	99				
I.45	Moravia, Hrottowitz	1,350	128.3	28	112.8	9								
I.46	,, Hubertskirch, (Sudeten Mts.)	2,300	102.3	78					100.4	8				
I.47	,, ,, ,, ,,	2,300	123.2	31										
I.49	,, Parchowitz	1,150-1,310	127.0	12	113.2	7							79.4	10
K.51	Slovakia, Cierny Vah, Liptovsky Hradok	2,630-2,790	109.5	12			96.0	5						
K.52	,, Murau, Liptovsky Hradok	3,150-3,430	123.1	32	104.4	4					98.1	9		
L.54	Scottish Larch from Wolfgang, Sweden		94.4	33	86.6	3			86.3	5			73.4	8
43/502	Scotland, Aldroughty, Morayshire	160	107.1	28	92.3	8	77.1	13	86.0	13	63.7	32	88.2	6
43/135	,, Lethen, Nairnshire	300-500											70.0	21
43/13E	England, North-East		90.0	45	97.9	5	75.6	12	87.3	13	77.8	18		
43/136	,, North-West		91.1	17	95.5	2	84.7	8	92.0	5	84.6	7		
43/1013	,, North-West Thornthwaite, *Good Trees*		102.0	9										
43/1012	,, North-West Thornthwaite *Cankered Trees*		111.3	30										
43/1001	Wales, Brechfa		96.1	17										

Phenological Studies

Flushing. A study of differential flushing in relation to provenance was begun in the spring of 1949 and repeated in 1950 at all five English centres. The basis of assessment was five phenological stages which have been laid down for similar studies in other fields of investigation: Stage I—buds resting, scales adpressed; Stage II—buds expanding, scales free; Stage III—buds open, needle tips visible; Stage IVA—needles extended, leaf bundles compact; Stage IVB—leaf bundles fully expanded. The data which are presented in Table 21 show the percentage of trees in each provenance which had reached Stage III at the time of assessment. In order to enable a clearer interpretation of the results to be obtained, comparison is made only of provenances which are replicated at three or more centres. This data gives an indication of the earliness or lateness of flushing of the various provenances.

FLUSHING ORDER FOR TWENTY-ONE RACES REPLICATED AT THREE OR MORE CENTRES MEAN PERCENTAGES OF TREES WHICH HAD REACHED STAGE III* OR BEYOND AT FIRST ASSESSMENT MARCH, 1949 AND 1950

Table 21

Mark	Origin	Alt. Feet	1949		1950		Mean	
			%	Order	%	Order	%	Order
A.1	Austrian Alps Bluhnbach	1,970	73.7	9	54.0	4	63.8	6
A.4	,, ,, Innsbruck	2,800-3,120	49.0	19	43.0	11	46.0	19
A.5	,, ,, Krumbach	1,970	64.7	15	41.7	14	53.2	15
A.6	,, ,, Lamerau	2,300	81.2	4	47.0	8	64.1	5
A.8	,, ,, Murau-Murau	2,950-3,280	78.2	5	61.2	2	69.7	2
A.13	,, ,, Steinach-Muhlbach	2.950	72.7	11	43.7	10	58.2	11
A.14	,, ,, Waldstein	1,640-1,970	81.6	3	67.0	1	74.3	1
B.15	,, ,, Michael	5,250-5,900	85.7	1	48.0	7	66.8	3
C.25	Italian Alps, Val Venosta	—	76.0	6	55.0	3	65.5	4
D.27	Swiss Alps, Graubunden	1,410-2,130	59.2	17	36.0	19	47.6	16
E.28	Japanese larch ex. Denmark	—	82.0	2	39.8	15	60.9	8
F.29	German and Polish Lowlands, Harbke	500	73.4	10	46.2	9	59.8	10
F.30	German and Polish Lowlands, Neckargemunde	655-985	71.0	12	43.0	11	57.0	12
F.31	,, Neumunster	98-230	70.4	13	51.0	5	60.7	9
F.32	,, Proskau	330-655	46.0	21	35.2	20	40.6	21
F.36	,, Stolp	82-98	73.8	8	51.0	5	62.4	7
K.52	Slovakia Murau	3,150-3,430	56.3	18	37.3	18	46.8	18
L.54	Scottish ex Sweden	—	49.0	19	39.7	16	44.3	20
43/502	Scotland, Aldroughty	160	60.8	16	33.4	21	47.1	17
43/13E	England North-east	—	75.0	7	38.8	17	56.9	13
43/13G	England North-west	—	69.2	14	41.8	13	55.5	14

* Stage III=needle tips visible.
In the case of Savernake, Stage IV (see above) was used.

A study of these data shows that phenological behaviour is a character of race, though in some cases more well defined than in others. It is observed that geographic groups conform, in general, to a similar pattern inherited, no doubt, from the closely related conditions of their natural habitat.

Earliest of all was the Siberian larch, which has suffered severe frost injury almost every year since it was planted, and has failed completely at two out of three sites. The two groups of seed lots from the Austrian Alps, Mark A (below 4,100 feet) and Mark B (above 5,250 feet) were, with the exception of

Races A.4 and A.5, conspicuously early at all five centres. The "standard" race, A.14 Waldstein, proved to be one of the earliest flushing lots at all centres.

Next in flushing order came the various origins from the German and Polish coastal plain and the West German Lowlands. These were rather diverse in that three of the seven lots in the collection have shown a marked tendency to flush much later than the other four. It is interesting to note that Dr. Schmidt also recorded that different behaviour and losses in the nursery were shown by several members of this group.

The next group to flush was that from the Italian Alps, followed closely by the two Scottish larches and the Swiss Alpine group. Latest of all the International lots to flush at all centres were the two groups from Slovakia and Moravia.

Of the five home origins included in the collection, two from England (North-east and North-west) flushed shortly after the earliest continental lots. Two others from Brechfa, South Wales, and Thornthwaite, North-west England, were among the last lots to flush.

At all centres the effect of shade and exposure to wind caused a considerable delay in the onset of flushing. Differences between the various provenances were also more marked in the early stages of flushing.

A comparison of the flushing assessment data for the two years 1949 and 1950 indicates that with only a few exceptions the general response of the various provenances to climatic influences does not vary very greatly from one year to the next. The only lots which showed any great variation in earliness of flushing between the two seasons were: Mark E.28 (Japanese larch), F.31 (Neumunster), A.4 (Innsbruck) and 43/13E (England North-east).

Races which were among the first eight in flushing order in both seasons were: C.25 (Val Venosta), F.36 (Stolp, Pomerania), A.6 (Lamerau), A.8 (Murau-Murau), A.14 ("standard" race—Waldstein), B.15 (Michael). All but one of these lots, F.36, are from sources in the Italian and Austrian Alps.

Several lots were consistently late flushing, of which the following were among the last eight in both seasons: D.27 (Graubunden), F.32 (Proskau), K.52 (Murau, Slovakia), L.54 (Scottish ex Sweden), 43/502 (Scotland, Aldroughty), A.5 (Krumbach). It is noted that these lots are from widely separated geographic regions.

Relations between Growth Rate and Earliness of Flushing. No consistent relation is apparent between rate of growth and earliness of flushing. It is interesting to note, however, that the Moravian and Slovakian groups of origins which have shown exceptional vigour were among the latest to flush. The German and Polish Lowlands group (Mark F) is variable but it is worth recording that Race F.32 (Proskau), one of the most vigorous races in the trial, was also one of the last to flush.

Among the Alpine origins, which showed the poorest growth, a large proportion were early flushers, notably Races C.25 (Val Venosta, Italy) A.8 (Murau-Murau, Austria) and A.1 (Bluhnbach, Austria).

Leaf-fall. Assesment of differential leaf-fall was carried out at the end of the 1949 season in order to ascertain the length of the growing season for the various provenances. Races which showed a relatively short growing season were: K.52 (Murau, Slovakia), A.4 (Innsbruck, Austria), A.5 (Krumbach, Austria), and D.27 (Graubunden, Switzerland). Those showing a long growing season were: A.1 (Bluhnbach, Austria), A.6 (Lamerau, Austria), A.13 (Steinach-Muhlbach, Austria) and E.28 (Japanese larch).

Comparing these results with the growth data for 1950, no consistent relationship is apparent.

(*b*) New Work on European Larch

The second and last part of the trial of various provenances of European larch, in places where previous European larch crops have suffered from "die-back", was planted at Drumtochty Forest, Kincardineshire; Thornthwaite Forest, Cumberland; and Coed-y-Brenin Forest, Merioneth. Of the first year's planting, one Scottish provenance (Farigaig) suffered heavy casualties in all forests, and despite enquiry, the reason remains obscure. It is improbable that one provenance which behaved normally in the nursery should be unusually susceptible in the forest, but no extraneous cause which might account for the heavy death rate was traceable.

Japanese Larch

In 1934 a collection of seed lots was received from Japan and planted out at several forests in Scotland. In 1948, these experiments came under the control of the Research Branch. The seed came from fourteen different origins in Nagano Province, Honshu, Japan, and of these, eight were on Mount Ontakesan, though the differences between the latter, whether of localities or of parent trees, are not on record. The natural home of Japanese larch in which seed collections are normally made is somewhat restricted, and covers an area roughly 150 miles by 150 miles. The seed lots comprised a fair sample of the whole province. The elevation above the sea of the parent trees is unfortunately not recorded for any of the seed lots. The experiments at Drummond Hill, (Perthshire), Knapdale (Argyll) and Strathyre (Perthshire) forests were assessed in 1948, prior to the first thinning, and though the plots in each forest were not replicated, each site is sufficiently uniform for comparisons between provenances to be made. The results of these experiments do not show any consistent differences. The mean height and mean girth of all provenances is very similar and none of them has shown any greater or less vigour at all three sites, but the size of the trees now varies considerably with the site of the experiment, the mean heights being as follows: Knapdale 26.8 feet, Strathyre 18.9 feet and Drummond Hill 34.2 feet. Assessments were also made of the average lean of the trees, this being determined by measuring the horizontal distance between the bole of the tree on the side away from the lean, and the top of a vertical pole ten feet high sited at the foot of the tree. Here again no consistent differences between provenances were found, but there was a very definite site difference. On the exposed west coast at Knapdale (elevation 500 feet) the average lean of all lots was 19.2 inches from the vertical at a height of ten feet. At a much greater elevation (1,100-1,300 feet), but less exposed to oceanic winds, at Strathyre Forest, the lean was 15.2 inches; and at a rather lower elevation (550-700 feet) in Drummond Hill forest, still further east, and least exposed, the lean was 13.4 inches. All trees were leaning in approximately the same direction in each experiment. The form of the stem was classified visually into the three categories normally used in sample plot work, viz. (I) trees with good stem form, (II) trees with slightly defective stems and (III) trees with very defective stems. The percentage of stems in each class was calculated but showed no consistent differences between provenances. The number of cankers on the stems up to a height of ten feet from the ground was also recorded. No consistent differences were found between provenances, but at Knapdale on the west coast the mean number of cankers per tree was 0.09, in the high elevation plots at Strathyre it was 0.23, and at Drummond Hill no cankers at all were found. From these experiments it appears that differences between provenances are small and not

likely to be made apparent without a very precise test. The effects of exposure and the elevation of the site are clearly evident, both in vigour of growth, in the lean of the tree and in its susceptibility to canker.

Scots Pine

The series of experiments with pine of different provenances was continued on the west coast. Here trouble from wind-blast causing browning and loss of needles occurs. Further study (e.g. at Achnashellach forest, Wester Ross, Expt. No. 22) suggested that poor nutrition is probably a predisposing cause. Therefore in the new experiments at Salen forest, Isle of Mull, and Asknish and Strathlachlan forests on opposite shores of Loch Fyne, the different provenances were planted both by older methods with little ground preparation and no manure, and with the aid of ploughing or intensive hand preparation and phosphate manuring. A number of Scottish provenances, both west and east coast, were included, together with some from Norway. Though older experiments in the eastern part of Scotland indicate that the coastal Norwegian pine grows slowly, it is hoped that it may prove faster and more resistant to blast near the sea on the west coast.

Results of experiments at Findon (Easter Ross), Roseisle and Teindland (Morayshire) forests confirm the superiority of pine of Scottish provenance to that of foreign origin. (Compare the results of a similar experiment in Thetford forest, in the *Reports on Forest Research* for 1949 and 1950).

The oldest experiment, at Teindland forest (No. 32, planted in 1928) showed significantly poor growth amounting to failure of northern Finnish provenances, while the southern Finnish (Viborg) seed produced trees of inferior height growth. Between two Scottish provenances (Beaufort, Inverness-shire, and Pitgaveny, Morayshire), two Latvian provenances and Hagenau, Bas-rhin, there were no significant differences, partly due to considerable variation in this site. After the first thinning in 1951, the basal area of the main crop of the home and Latvian provenances was significantly greater than that of the Haguenau and Viborg lots. The basal area of thinnings removed was approximately proportionate to that of the main crop. The form of the trees of the Viborg provenance was good. The two Latvian lots varied from plot to plot, but coarse wolf trees were numerous and the crop had an ugly appearance. The two home provenances appear to be likely to give the most valuable crops.

GROWTH DATA OF SCOTS PINE PROVENANCE EXPERIMENT AT TEINDLAND. PLANTED, 1928

Table 22

Identity No.	Provenance		Altitude feet	Mean Height ft. 1947 season, age 20 years	Basal Area sq. ft. per ⅓ acre plot 1951 season age 24 years	
	Origin	Latitude N.			Main crop	Thinnings
25/27	Viborg, Finland	61	160-320	14.5	6.12	1.23
28/501	Latvia	56-58	—	18.2	9.48	2.61
25/67	Riga, Latvia	57	—	16.3	7.81	1.67
25/503	Pitgaveny Estate	57°40′	0-50	16.9	8.61	2.84
25/502	Beaufort Estate, Inverness*	57°27′	100	18.5	10.12	3.61
25/25	Hagenau	48°45′	—	16.1	7.50	1.51

* Sawmill Wood. Reputed remnant of old Caledonian native pine.

[*Table 22 continued on next page.*

Table 22—*continued.*

Identity No.	Provenance: Origin	Provenance: Latitude N.	Altitude feet	Mean Height ft. 1947 season, age 20 years	Basal Area sq. ft. per ⅓ acre plot 1951 season, age 24 years: Main crop	Basal Area sq. ft. per ⅓ acre plot 1951 season, age 24 years: Thinnings
	Standard error of the means			±1.0	±0.76	—
	Differences necessary for significance at 5% level			3.2	2.40	—
	Partially failed plots:					
25/69	Kittila, Finland	67°30′	650	2.4	1.76	Nil
26/F8	Ahtari, Finland	62°30′	475	6.6	3.53	0.30

At Findon, (Expt. No. 1, planted in 1929) the home provenances were approximately double the height of any of the foreign ones, and those from the north of Finland and southern Europe were mainly dead or dying. There were no significant differences between any of the home provenances. No measurements descriptive of the form of the trees have been made. Visual scoring by the Geneticist gave the following results, the lowest score indicating the tree of best stem, branch and crown form: Strath Conon (Ross) and Loch Fyne (Argyll) 16, East England (Norfolk & Suffolk) 19 and Innes (Moray) 20. The Finnish provenances all scored 14 or 15. The conclusion reached in past inspection reports is that Innes has produced best results as a crop, taking into account both vigour and form, and that East England ranks as the second best. It is of interest to note that, though the East England pine is commonly believed to have been introduced from Scotland and is in general found to be of superior quality and growth, Selby in 1842 remarked that plants raised from the seed of the Norfolk trees "are so deteriorated in constitution, that few of them when planted live for more than 25 years"! The mean needle lengths of the provenances were also calculated, which confirms that the Finnish provenances have much shorter needles, (27 mm. or 1 in. approx.) than all other provenances, which are all over 30 mm. (about 1¼ in.). The native provenances have needles about 35 mm. (about 1½ in.) long. The contrast in colour of needle has been remarked on at all stages of growth, the home provenances being dark green and the foreign yellow green.

SCOTS PINE PROVENANCE TRIAL AT FINDON FOREST. PLANTED 1929
LOCALITY DATA, MEAN HEIGHT, GROWTH AND NEEDLE LENGTHS

Table 23

Identity No.	Provenance: Origin	Provenance: Latitude N.	Provenance: Altitude feet	Mean Height ft. 1950 season, age 22 years	Mean Needle length mm.
	GROUP I HOME PROVENANCES				
25/505	Strath Conon, Ross-shire	57°30′	100-500?	20.1	34
26/502	Innes, Morayshire	57°30′	0-100	22.0	35
26/501	Darnaway, Morayshire	57°30′	200-500	21.0	34
25/504	Loch Fyne, Argyllshire	56	sea level?	19.5	35
26/17	East England	52°30′	50-200	22.5	36
			Mean	21.0	35

[*Table 23 continued on next page*

Table 23—*continued.*

Identity No.	Provenance: Origin	Latitude N.	Altitude feet	Mean Height ft. 1950 season, age 22 years	Mean Needle length mm.
	GROUP II FINLAND				
26/F6	Sodankyla	67°15′	625	Mainly dead	—
26/F7	Pieksamaki	62°30′	400	8.8	26
26/F8	Ahtari	62°30′	475	12.4	27
26/F1	Lammi, Evo	61	300	10.2	27
26/F3	Raivola	60°15′	150	14.5	28
			Mean	11.5	27
	GROUP III BALTIC AND RUSSIA				
26/54	Selburg, Latvia (var. *rigensis*)	57	390	10.0	32
25/70	Ural Mountains (var. *uralensis*)	57-67?	?	7.4 Many dead	37
	GROUP IV SOUTHERLY LATITUDES				
26/4	Borzham, Georgia (var. *hamata*)	42	3,500	9.6	35
26/9	Sierra Nevada, Spain (var. *nevadensis*)	37	6,500	4.8 Many dead	34
	Standard error of the means			±1.2	±1.3
	Differences necessary for significance 5% level			3.5	3.6
	1% level			4.7	4.8
	0.1% level			6.2	6.4

There are single large plots of one-quarter to one-third acre of each of the home provenances adjacent to the replicated experiment, and in these sample plots have been established. They give results which are closely comparable with the replicated experiment, as will be seen from the following table, and in addition they will give reliable yield data over a long period of time. The small plot experiment will have to be abandoned because the plots now interfere with one another.

SAMPLE PLOT DATA. FINDON SCOTS PINE PROVENANCE TRIAL

Table 24

Identity No.	Provenance	Plot No.	Top Ht. feet	Volume in cubic feet quarter-girth measure over bark per acre: Main crop	Thinning	Stem form (% in three classes): I	II	III
25/505	Strath Conon	246	30½	656	236	37¾	62	¼
26/502	Innes	247	32½	644	231	9	88	3
26/501	Darnaway	245	32	616	192	23½	76¼	¼
25/504	Loch Fyne	248	28	413	127	23¾	75¾	1
26/17	East England	249	33½	686	177	43¼	56½	¼

The East England provenance appears to be growing faster in height than the others and establishing a superiority in the form of the trees.

In Roseisle forest a similar experiment (No. 2) was planted in small "Anderson" groups, with seedlings in 1930 and transplants of the same seed lot in 1931.

Both the seedlings and transplants of the Darnaway provenance have done better than any of the others, and they may be regarded as significantly superior in height. There are no significant differences between the Glen Moriston, Loch Maree and Abernethy provenances, which are all considered to be remnants of the native Caledonian pine forest. The west Norway provenance is very inferior in growth, and in survival, many of the groups now being blank. No measurement of other characteristics has been made, but in appearance the Darnaway trees are rough and coarsely branched. The Loch Maree group are often but less consistently coarse, while the Abernethy trees are variable in appearance. The Glen Moriston provenance is the straightest and finest-branched of all, and with few exceptions is of good form.

SCOTS PINE PROVENANCE TRIAL AT ROSEISLE FOREST
MEAN HEIGHT AT END OF 1947 (i.e. AGE 18 OR 17 YEARS)
(The mean of the three tallest trees per group)

Table 25 Height in feet

Identity Number	Provenance	1 yr. seedlings	1 yr.-1 yr. transplants
29/554	Glen Moriston, Central Inverness-shire	16.4	17.3
29/547	Loch Maree, Wester Ross	18.0	16.6
29/549	Abernethy Forest, Eastern Inverness-shire	17.4 ± 0.48	16.4 ± 0.47
29/559	Darnaway Estate, Morayshire 70 yr. old trees	18.6	19.4
29/560	Darnaway Estate, Morayshire 18 yr. old trees	19.7	18.2
	Differences necessary for significance 5%	1.4	1.4
	Differences necessary for significance 1%	1.8	1.8
26/503	West Norway	5.6	6.4

Pinus contorta

An experiment to test the value of seven seed lots of *Pinus contorta* of different origins was laid down at Clocaenog Forest, in the Ty'n y Waen (Sheepwalk) Area in 1934. The collection included four lots from inland regions of British Columbia at medium elevations, one lot from Alaska and two lots from the coastal belt of the United States of America at elevations of below 500 feet.

The site is a very exposed area of *Calluna* moorland at an elevation of 1,380 feet. The ground has a gentle slope with good natural drainage and a south-east aspect. The soil is a peat varying from two to several inches in depth. In general the conditions prevailing on this site would be classed as severe from an afforestation point of view.

The growth and appearance of the two coastal lots (Ident. No. 34/39 U.S. Coast; Ident. No. 34/40 Olympic Peninsula, Washington) are very good and they are, in general, superior to the inland origins on this site. Many plots have suffered injury by windblow.

A study of form shows that the coastal lots are more heavily branched, having a greater number of branches per whorl, thicker branches and also a slightly greater crown spread. Their needles are, however, shorter and stiffer than those of the inland origins. The mean data for comparable plots, measured in 1951, is as follows:—

PINUS CONTORTA PROVENANCE TRIAL AT CLOCAENOG FOREST

Table 26 Measured 1951

Date of Planting	Identity Number and Provenance	Height (feet)	Branches per whorl at Breast Height	Branch girth (in.)	Crown spread (feet)	Needle length (mm.)
1937	34/39, West Coast of United States 50-100 feet	17.7	5.8	2.8	9.0	49.2
1937	34/40, Olympic Peninsula, Washington, 300-500 feet....	20.6	5.8	2.3	8.0	44.2
1934	31/26, Mt. Ida, British Columbia	20.5	brashed	—	8.0	61.7
1934	31/49, E. of Kamloops, British Columbia over 1,310 feet....	21.4	4.4	2.1	7.6	63.0

Among the inland origins the Kamloops race is very promising. The more heavily branched coastal lots have proved very effective in suppressing the dense vegetation.

Corsican Pine

A provenance trial using four origins of Corsican pine was laid down at Clocaenog Forest, on Cefn Du (Pincyn Llys section) in 1951. The plants were raised from seed lots collected in Italy, Corsica, Spain and East Anglia and were planted in screefed patches in the natural surface.

There is little to be said at present about this experiment except that losses at planting were heaviest in the case of the Spanish lot (38 per cent) and lowest for the Italian lot (8 per cent). Losses for the East Anglian and Corsican lots were 23 and 25 per cent respectively.

Douglas Fir

Seventeen seed lots of Douglas fir collected from a wide variety of sites in Washington and Oregon were presented by Mr. F. E. Manning. Mr. Leo Isaac of the Pacific North-west Forest Experiment Station, United States Forest Service, co-operated in providing site data. Half of each lot was sown at Newton Nursery, Morayshire, and half placed in cold store. There were no significant differences in their growth in the first season.

An experiment planted at Glentress Forest, Peebles-shire, in 1943 affords a comparison between the green Douglas fir from Vancouver Island (three separate seed collections) and the grey variety *caesia* from Salmon Arm and Prince George, British Columbia, Canada. The latter are on the average taller and better shaped trees, and in the summer of 1951 they proved far more resistant to attack by *Adelges cooleyi*.

FOREST ECOLOGY

By J. M. B. BROWN
Forest Ecologist

Growth of Beech in Britain

Work on beech has been mainly an extension of the assessments of height growth of young beech crops in relation to environmental factors, and more detailed observations on the causes of forking in the pre-brashing stage. Attention has also been given to the ecology of chalk soils and the natural and semi-natural plant communities which they bear. All these lines of work are still being followed and call for only brief notice at this stage. Some of the information collected was included in a full report of an ecological survey of British beechwoods, which was got ready during the year for publication as a bulletin.

Early Growth of Beech in Britain

Conservators of Forests in the south and east of England co-operated in this investigation, producing 240 representative assessments of growth: these relate to plantations ranging in age from three to fifty years (rarely older, up to 97 years) and are distributed as follows:

South-east England	133
East England	90
South-west England	10
Forest of Dean	7

This reflects the predominantly south-easterly distribution of beech in Britain. These assessments, together with about 150 made by the Research Branch, have been summarised and will be fully reported in due course. Meantime a few general observations can be made on the data.

(1) Most of the assessments show a very satisfactory rate of growth, which compares favourably with early growth in German and Danish beech forests. This is partly due to the latter representing naturally regenerated crops, held back at first by shade and root competition. Some of the cases in which the yearly increment fell much below twelve inches could be traced to inadequate tending during the war.

(2) There is no close relationship evident between early growth of beech and soil factors. But there is a tendency for the finely loamy soils and the deep sands or sandy loams to show better results than shallow chalk soils, or clayey soils with impeded drainage in the subsoil. Records from clay soils are regrettably few and the plantations concerned are mostly under twenty years. In several cases the early growth of beech on clay soils has been satisfactory to distinctly good and the further development of these crops will be watched with interest. Unfortunately the investigations in mature beechwoods have provided little information about beech growth on clays. Thin chalk soils are notoriously liable to summer drought, especially on south aspects. Early growth of beech is then always slow and often interrupted by dieback, unless there is considerable shelter from the relief, or from associated trees.

(3) The forms used for assessment always included the character of the preceding crop (forest or other) and indicated whether the beeches had been raised in the open, in mixture with another species, or as underplanting:

the retention or removal of nurse trees was also recorded. It appears that, on the drier sites, where, because of full exposure, or low rainfall, or an unretentive soil, the young trees have difficulty in making good their water loss, shelter from associated trees can be a very material aid to establishment. Apart from this, establishment and early growth are as a rule distinctly more rapid on clear-felled old woodland than on open downland or heath. In fact, however, most former woodland areas bore, at the time of acquisition, considerable regrowth of birch seedlings, or coppice shoots, and it is now the practice to make every use of this, restricting the expensive work of clearance to the minimum. There are instances of good early growth of pure beech crops on open ground, where the exposure was slight and the soil moisture supply good. But in general the establishment of beech on treeless pasture or heath still presents difficulty.

(4) On the whole, early growth appears to have been better in the districts with higher rainfall (Goodwood area of Sussex, Collingbourne, Forest of Dean) than the average for the regions represented. Although the high rainfall and cooler summers of an oceanic climate may be unfavourable to the perpetuation of natural beechwood, the individual crop appears to thrive on them.

Forking in Young Beeches

Careful observation of many individual trees through the growing season of 1951, and occasional notes in all the other plantations inspected, showed that incipient forking is nearly always associated with injury to the leading shoot, and that trees which make renewed growth after midsummer (or produce "Lammas shoots") are specially affected. A Tortricid caterpillar (later identified as *Peronea ferrugana*) had previously been found responsible for serious damage to shoots in late summer and early autumn. In 1951, a gall midge of the genus *Contarinia* was found to be very prevalent in the buds and late summer sprouts in several districts. Several larvae are usually found in an opening bud, and death of the bud usually follows. Die-back of tips in summer is not always, however, associated with evident insect injury, and it is believed that physical conditions of the atmosphere may be concerned. Further investigation is pending.

The factors upon which secondary shoot extension in late summer depend are still insufficiently understood. In the rainy late summers of 1950 and 1951 such extension was very common, and this suggests that soil water has some controlling influence. At the same time shade is concerned in some negative way: it has been observed, both under experimental conditions and in the field, that strongly shaded young beeches rarely produce Lammas shoots. In view of the interest in the origin of stem defects in young beech crops, this clue seems to be worth following up.

Chalk Grassland Communities

The natural, or semi-natural, chalk grassland communities of the south of Britain are not merely of academic interest. They may be used as guides in the choice of species, or as indices of the probable performance of beech or other trees planted on them, and their examination may provide information of silvicultural value.

On the shallow rendzina soils the chalk pasture in the southern counties is largely dominated either by *Zerna erecta* (*Bromus erectus*) or by *Festuca ovina* agg., although several other grasses may be abundant, or locally dominant. For long it was a puzzle why *Zerna* was dominant at Friston, Sussex, and *Festuca* at Buriton and some other Hampshire forests. There is now a good deal of

evidence that *Zerna* is the natural dominant, persisting, however, only on undisturbed ground. After heavy grazing, or a few years under the plough, *Zerna* disappears (except here and there on "headlands") and other grasses more tolerant of man's activities increase their range. It is not clear what bearing this may have on silviculture: but it may be that *Festuca ovina* dominance on chalk grassland betrays recent tillage, with the ensuing drainage of fertility and possibly some soil erosion.

Influence of Shade on Increment, Stem Form and Health of Beech Plants in the Nursery

Lay-Out of Experiment

This experiment was set up in Markham Oak Nursery, Alice Holt, in February 1950, with 24 plots (six replications of four treatments), each measuring six feet by six feet and carrying 49 beech transplants at a spacing of 10 inches each way.

The treatments were:

0 (Control)—Plants receiving full (100 per cent) daylight.
1—Light reduced by an overhead lath screen to about 50 per cent daylight.
2—Light reduced by a similar, closer screen to about 20 per cent daylight.
3—Light reduced by a lath and hessian screen to below 5 per cent of full daylight.

Periodic measurements of the light transmitted by the screens were made throughout the growing seasons of 1950 and 1951. A photo-electric cell was used and the measurements were made in dull weather some time within three hours of noon between early May and mid-September. On the evidence of these measurements, small adjustments were made to the screens at the beginning of each growing season, partly to ensure that they accorded with the plan, but more especially to ensure that all the six plots included in one treatment received about equal light intensities. The relative light intensity (i.e. the light expressed as a percentage of the light measured in treatment 0) fluctuated a little, particularly under the hessian (treatment 3): but these fluctuations were not regarded as serious. After the final adjustments in the early summer of 1951, the position was that treatments (2) and (3) were receiving rather less than the 20 per cent and 5 per cent of full daylight which were aimed at, and the last set of measurements, taken in good conditions on 5th September, 1951, showed the following mean values for the relative light intensity under the four treatments:

0—100%; actually about 1,425 foot candles.
1— 49.7%; ,, ,, 700 ,, ,,
2— 17.9%; ,, ,, 250 ,, ,,
3— 3.75%; ,, ,, 53 ,, ,,

The plots were planted up at the end of February, 1950, with one-year-old seedlings from Buriton nursery, and the screens were put over at once. The plots were edged with a single row of small Sitka spruces to cut down side light and draughts, and to create a favourable microclimate for growth. In the shaded plots this was later augmented by a partial side screen of hessian, after the first light measurements indicated that rather too much side light was getting through. As the experiment was only concerned with the shade factor, adequate soil moisture was assured by the application of water when required. This was mainly given to the open plots during the warm dry weather in June and July, 1951, but one general watering was given about mid-summer in each season.

Observations and Measurements

In addition to the measurements of light intensity, regular records were made of the condition of the plants, the occurrence of insect attack and secondary shoot extension (Lammas growth) and of the moisture state of the soil. Observations were also made on flushing and leaf fall dates under the different treatments. A complete assessment of total height and current increment in October, 1950, showed a small difference in favour of treatment 0 (full light), which was mainly due to the greater frequency of late summer shoot extension in this treatment. The check occasioned by transplanting and the dry spring and early summer caused poor growth generally in 1950, and it was recognised that the second season of the experiment would be the decisive one. The full assessment in autumn 1951, included the following measurements on the twenty-five plants which formed the central square in each plot:

(*a*) *Leaf.* Number and dry weight of leaves on every plant: leaf size and total leaf area for every plant in two of the six replications.
(*b*) *Shoot.* Total shoot length, yearly increments (split into spring and summer portions) and dry weight for every plant.
(*c*) *Root.* Depth of penetration, length (stretched) of longest root and dry weight of root system on every plant.
(*d*) Detailed records of forking, dieback and insect damage for each plant.
(*e*) Notes on habit of shoot and root and the characters of buds, leaves and bark for each plot.
(*f*) Photographs of three representatives of each treatment.

Results

A full report will be prepared when the data have been further examined and statistically analysed. Meantime the general effects of shade on the growth, health and form of the three-year-old beech plants may be thus summarised:

Leaves. The leaves of shaded plants are markedly fewer, thinner, lighter in weight and darker green: except in the moderate shade of treatment (1), they are individually smaller in area. They are flatter and less crimped; downier and somewhat softer and more flaccid: they are also conspicuously more horizontally arranged on the twigs. Under shade, too, the leaves appear somewhat later in spring and they change colour and fall rather later in autumn.

Shoots. Under increasing shade the axis of the shoot becomes progressively less erect, thinner, less branched and lighter in weight. The height growth may be slightly improved by moderate shade (50 per cent), but falls off at light intensities much below 50 per cent. This is connected with a reduced frequency under shade of mid-summer shoot extension (Lammas growth), which in turn is evidently associated with a lower incidence of dieback of shoots and a lower frequency of forks. Fig. 1 shows clearly the contrast between the stout, vigorous, much branched shoot of the tree in full light and the slender, horizontally inclined shoot of the deeply shaded tree, bearing only few, more or less horizontal, twigs. The buds of shaded trees are distinctly smaller and, as noted already, begin growth later in spring.

Roots. The roots of shaded beeches were, like the shoots, thinner, much less branched, lighter in weight and somewhat less deeply penetrating. At 50 per cent light intensity there was a slight reduction in the root/shoot ratio, as compared with the control: the ratio scarecely seemed to undergo any further reduction in the more shaded plots.

Insect injuries. Injuries by insects were in general much less frequent under shade. This may be partly ascribed to easier access to the uncovered trees, and partly to the predilection of certain insects for the tender Lammas sprouts from mid-summer on. Of these insects certain Tortricid larvae (Lepidoptera)

and gall midges of the genus *Contarinia* were the most important. Several larvae of the Vapourer Moth (*Orgyia antiqua*) were detected, mainly on the unshaded trees. But the most widespread and troublesome insect in the plots was *Phyllaphis fagi*, which causes a white exudation on the lower surface of beech leaves in nursery and plantation. This was at first more prevalent on unshaded trees: but it proved more persistent, and caused some premature leaf fall in 1951, under moderate shade (Treatments 1 and 2). In the deepest shade *Phyllaphis* was scarcely seen.

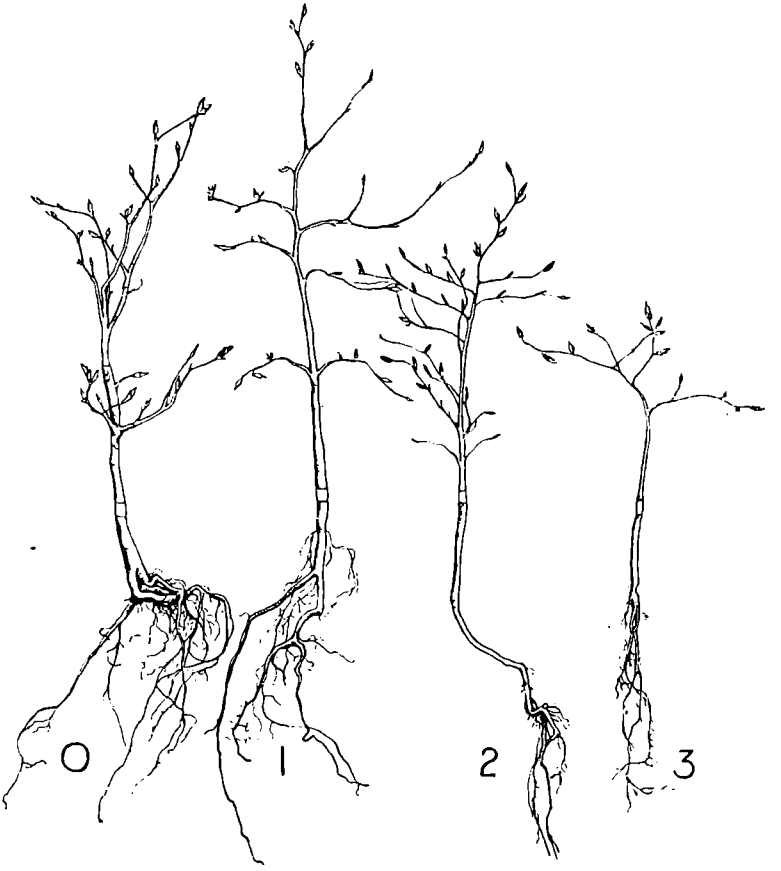


Fig. 1. Representative beech plants from four shading treatments.
0—Plants received full daylight
1—Light reduced to about 50 per cent. full daylight
2—Light reduced to about 20 per cent. full daylight
3—Light reduced to about 5 per cent. full daylight
The white ring indicates ground level.

Discussion

It is evident that the detailed examination of the data will show that the shading has had a profound influence on the form of the young beech plants subjected to these treatments during two years in the nursery. The effect on height increment appears to have been small—perhaps insignificant for the two intermediate degrees of shade. But even at a light intensity of 50 per cent of full daylight there is some reduction in dry matter increase of shoot and root;

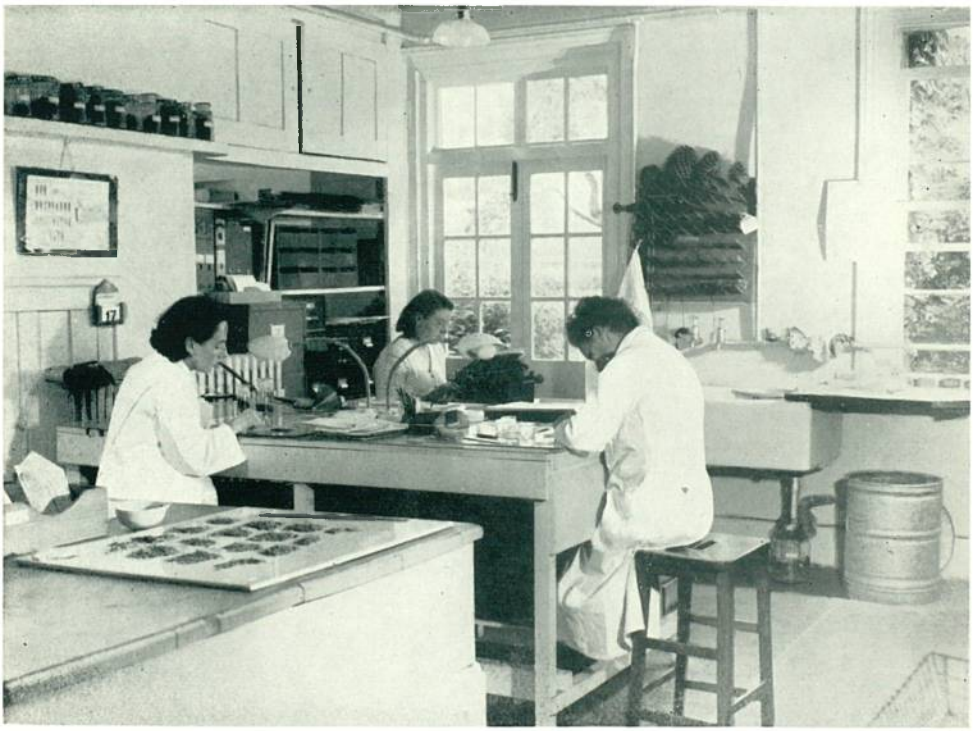


Plate I. General view of the Seed Testing Laboratory at Alice Holt Lodge.

Plate II. Counting germinated seed in a sample tested on a Copenhagen tank.

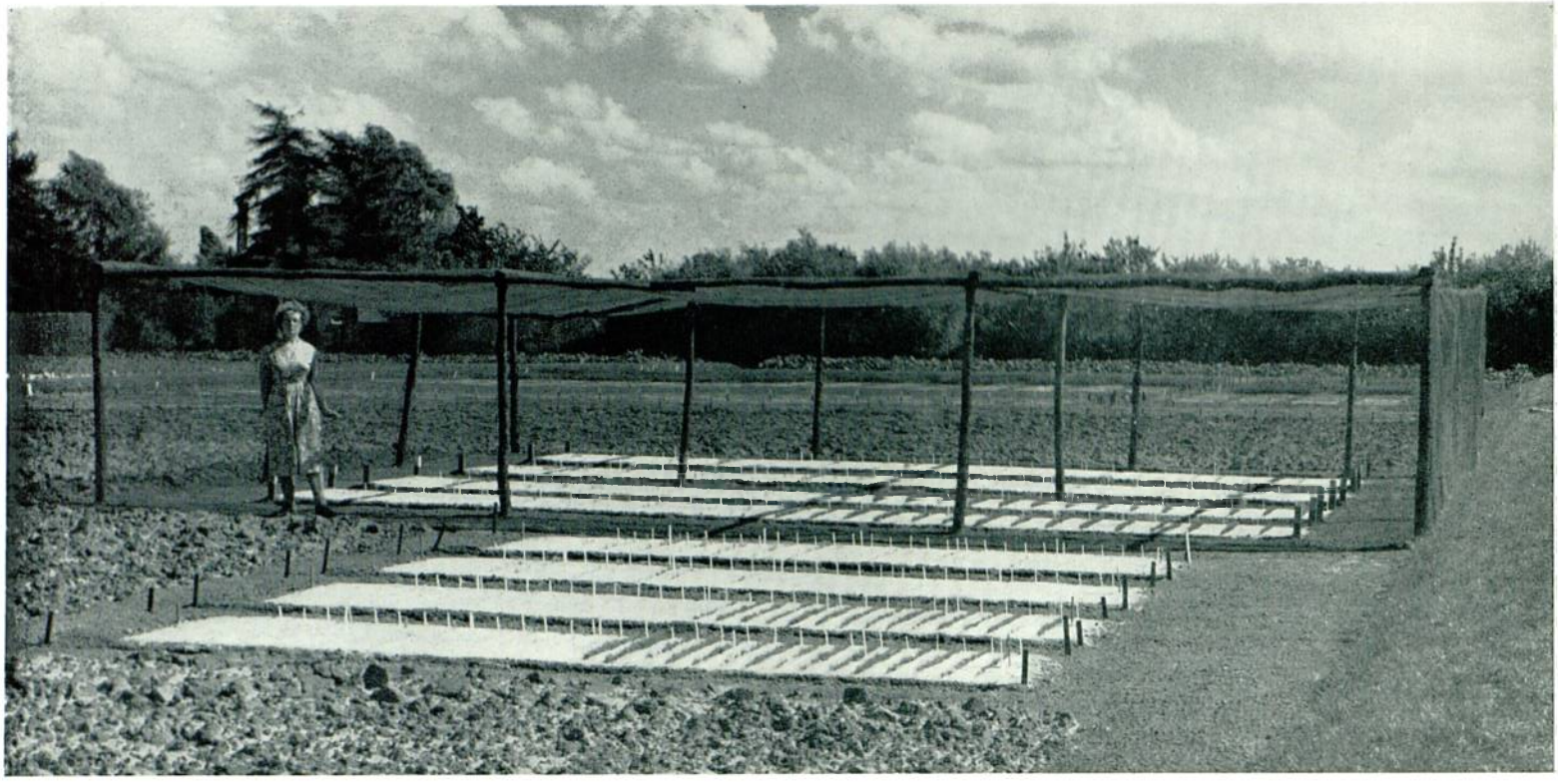


Plate III. Field tests of germination capacity at Kennington Nursery, near Oxford. The seedbeds in the background are screened against birds and rodents by fine mesh wire netting.

Plate IV. Typical control tree of Sitka spruce at Wareham Forest, Dorset. Experiment No. 70. Planted 1945, photographed April, 1952, after seven seasons' growth. Average height of plot 19.7 inches. No nursing or manure.

Plate V. Typical group of Sitka spruce in Experiment 70 at Wareham Forest, Dorset, planted in 1945 and photographed in 1952. Average height of plot 70.6 inches. Nursed with broom and manured with 2 ounces of bonemeal per tree.

Veneer side grafting of Corsican pine scion on Scots pine rootstock :

Plate VI. Inserting the scion into the basal notch of the rootstock. Note the veneer cut on the stock, which faces a similar prepared surface on the scion.

Plate VII. Tying with raffia. Note the good support secured at base and top of union.

Plate VIII. Veneer side grafting of Corsican pine scion on Scots pine rootstock. A successful union. Note the protecting wax covering. Grafted 25th February, photographed 5th July.

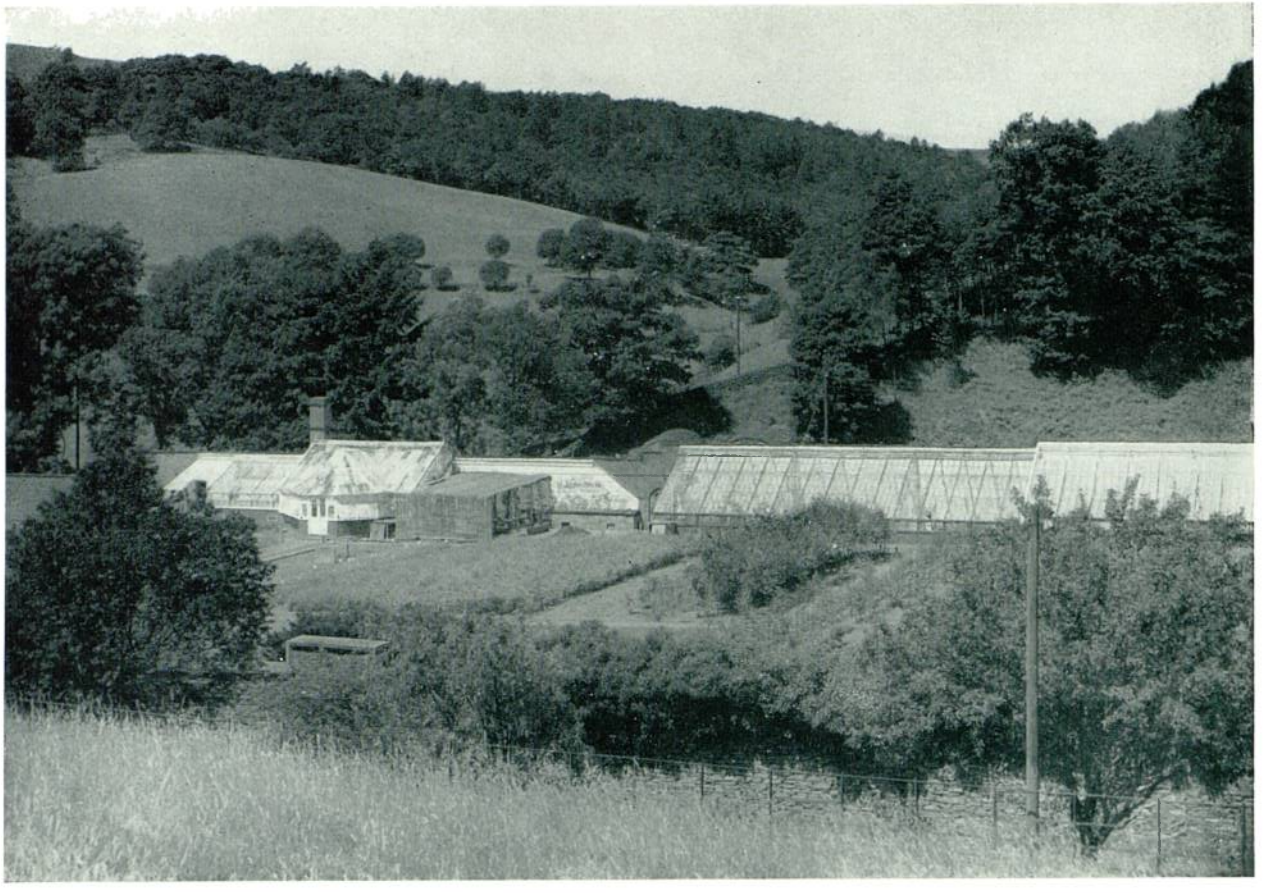


Plate IX. General view of the glasshouses and walled garden used for tree propagation at Grizedale Forest, near Hawkshead, Lancashire.

Plate X. Poplars of several varieties raised at Alice Holt Lodge for use in field trials, showing one year's growth from cuttings.

Plate XI. Giant Rotavator on trial at Alton Forest, Hampshire, clearing light regrowth of sycamore, ash, and birch.

and with increasing shade this becomes pronounced. The effect is due partly to the slenderness of the main axes, partly to the reduction of branching.

Of almost equal importance is the effect of shade on the form of the tree. Deviation of the shoot from the vertical was evident in most plants of Treatment (2) (18 per cent light) and became general and serious in Treatment (3). Concurrently there was a reduced tendency to renewed mid-summer or late summer shoot extension under shade: in Treatment (3) such secondary growth was practically absent. It has been observed in the field that stem defects in beech plantations which have outgrown the frost and rabbit menace are ordinarily a result of damage by insects, or by meteorological agencies, to the "Lammas" shoots, which are very frequent on young beeches in certain environments. In the experimentally shaded plants suppression of Lammas growths went hand in hand with reduced damage by insects and reduced diebacks of tips. There resulted, under shade, a reduction in forking; the upright tending branches of the fully lighted plants perhaps also increased the likelihood of forking in this treatment. Lammas growth, die-back and forks were, however, prevalent in the plants receiving 50 per cent light, and reduction of these factors first became conspicuous when the light was cut down to about 18 per cent. At this degree of shading, however, the reduction of dry weight increase is important, and the plants are in some danger of assuming the "table-topped" habit. There may be some intermediate light intensity in which a satisfactory blend of vigour and good stem form is achieved; but the experimental results appear to indicate that the improved form which moderate shade indirectly induces can only be secured at the price of some loss of vigour. The reduction of height increment, even after 80 per cent of the light is cut off, is, however, probably trifling. In general these inferences agree very well with the inferences drawn from many field observations and assessments on young planted and natural beech crops. But the field observations make clear at the same time that the instrumental causes of forking in young beech crops (Lammas growth, insect injuries, frost, sun scorch) are controlled by several factors of which shade is only one.

FOREST GENETICS

By J. D. MATTHEWS
Forest Geneticist

Progress of the Programme of Improvement of Tree Seed Sources

Improvement by Mass Selection

The location of suitable seed sources for current and future planting programmes continued. A survey of Scotland, covering all species in common use, commenced during the summer of 1951, and the counties of Moray, Banff, Aberdeen, Kincardine and Angus have been completed; some surveying was also done in east Perthshire.

Over 220 stands were assessed and classified as suitable (A or Plus and B or Normal) or unsuitable (C or Minus) for seed collection, with the results set out in Table 27. The classifications A or Plus and C or Minus remain unchanged from previous years but it became necessary to subdivide the category B or Normal. The new classification B+ is used for borderline cases where the accumulation of further knowledge is likely to raise the rating to A or Plus.

PLUS AND NORMAL SEED SOURCES IN THE EAST CONSERVANCY OF SCOTLAND *

Table 27 Area in acres arranged by species and age classes

Species	A or Plus	B+			B+ Totals	B or Normal			B Totals	Total Area of Seed Sources
		21-40 Years	41-80 Years	Over 80 Years		21-40 Years	41-80 Years	Over 80 Years		
Scots pine....	30	41	177	112	330	106	818	216	1,140	1,500
Corsican pine		1			1		34		34	35
Pinus contorta						3			3	3
European larch	10		67	110	177		249	97	346	533
Japanese larch	13	22	3		25	10	4		14	52
Douglas fir	3			4	4	16	30	2	48	55
Norway spruce								5	5	5
Sitka spruce		3			3	40	1		41	44
Picea omorika		5			5					5
Tsuga heterophylla			5		5					5
Beech				9	9					9
Totals	56	72	252	235	559	175	1,136	320	1,631	2,246

Improvement by Mother Tree Selection

The study of the rich collection of specimen trees of historical and botanical interest also continued during the year. Trees of this type occur singly or in small groups in arboreta, in older private woodlands and in State Forests with a long history of management. A central index of the more valuable early introductions of exotics is being built up, using the works of Loudon, Elwes and Henry and the reports of the two Conifer Conferences (1891 and 1931) as the principal sources of information

Improvement Based upon the Selection of Both Parents

The selection and propagation of a series of outstanding phenotypes (Plus trees) continued concurrently with the survey of seed sources. Twenty acres of ground have been set aside in Alice Holt forest for a central collection of clones from Plus trees. Representative grafts and cuttings are being established there in readiness for future breeding work.

Study of the Technique of Tree Breeding

Vegetative Propagation

The most important group of techniques in tree breeding are included under the general heading of vegetative propagation, which includes the operations of grafting, budding, and the rooting of cuttings. Vegetative propagation is used to bring the breeding material together into a convenient place; to test the inherent quality of the selected phenotypes; to stimulate flower production so that controlled crossings can easily be made, and finally to establish seed orchards for the production of seed of improved strains in quantity.

Grafting, and the associated technique of budding, can be used to produce clones of the majority of the more widely-used coniferous and broadleaved tree species. Clones can also be produced by the rooting of cuttings, but this method is restricted at present to genera such as *Populus* and *Sequoia* which include species which strike relatively easily. The ability of a tree to strike from cuttings also appears to decrease with age in most species, and as the majority of Plus trees are older than fifty years the practice has limitations at present.

*Since this Report went to press, many of these stands have been destroyed in the great windblow of 31st January, 1953.

In grafting much depends on the type of scion material employed. It is often difficult to obtain the best scion wood from the older Plus trees and for this reason propagation falls into three distinct stages. First there is the initial "fixing" of the selected parents. A very suitable unit quantity is twenty grafts done on the most suitable rootstocks and under the best possible propagating conditions. The successful grafts from each tree are then put into a central collection, called for convenience the "tree bank", either as groups or in lines spaced twenty to twenty-five feet apart. When larger clones are required these first grafts can be used as the source of the material. If the groups or lines are conveniently arranged controlled "selfings" and crossings can be made in the "tree bank" to determine the quality of the progeny produced by the selected parents.

Secondly, clones are produced for the testing of the genotype of the Plus trees. This involves the use of some hundreds of grafted plants distributed in standard layouts over several different site types. The large-scale grafting required can only be done out of doors under the simplest possible conditions.

The final stage is the establishment of seed orchards. This aspect of grafting has not yet been fully developed, and it is probable that the majority of the very varied techniques, such as the top-working of established trees and the use of "dwarfing" rootstocks, employed in fruit orchard practise, will also find a place in tree seed orchards.

The experimental approach to grafting and budding cannot be ignored. Specialized methods have already been evolved in Denmark for oak and beech, and in Britain for walnut, and some modifications of the normal methods are desirable for other tree species. The chief factors leading to success appear to be correct choice and treatment of rootstocks, correct choice of scion material, good grafting technique, and adequate after-care of stock and scion. All the experience gained experimentally should be applied to the mass production of grafts over a considerable part of the year and in the open nursery. This is the only practical and economic method, and progress in breeding projects will largely depend on the evolution of suitable techniques.

Since September, 1950, the Research Branch has had the use of part of the walled garden and glasshouse space available at Grizedale Hall which is situated in the Forest of Grizedale, Lancashire. Plate IX shows a general view of this establishment. During 1951, the glasshouses were repainted and converted, and during the winter and spring of 1952, the first experimental grafting study was commenced. The methods employed, and some of the results obtained, are described below in the progress report for Corsican pine. The propagation unit at Grizedale will be used for three main tasks:

(1) The best possible conditions will be provided for the initial "fixing" of selected parent trees.
(2) Each important species will be taken in turn, and the best grafting techniques worked out for propagation under glass and out of doors. The most successful methods will then be used for the mass production of grafts in the open nursery.
(3) The selection of rootstocks for seed orchard purposes will be studied and the possibilities of using clonal rootstocks will receive increasing attention during the next few years.

Similar specialized units for the development of large scale propagation by cuttings are being built up at Alice Holt and Kennington Nursery, Oxford. The species at present under study are *Sequoia sempervirens* and the larches.

Flowering and Fruit Production in Forest Trees

Studies under this heading fall into four main groups. The first comprises general observations on the effects of age of tree, site conditions, cultural

methods and climate on the seed production of trees in Britain. As data accumulate attempts will be made to forecast future seed crops for the various species in different parts of the country.

Secondly there are the more intensive studies of the flowering and fruiting habits of the species included in breeding projects. Data are being collected at present on the effects of site, cultural conditions, climate and inherent characteristics on the age of first flowering and age of maximum seed production in Corsican pine, Scots pine and beech. Times of flushing, flowering and leaf fall are being recorded, as also are the relative distribution of male and female flowers on individual trees. The production and dispersal of pollen by small groups and plantations of European larch was studied in a preliminary way during 1951, in connection with the establishment of the hybrid larch seed orchard at Newton Nursery near Elgin, Moray.

In the third group of studies selected plantations are being subjected to various grades of thinning, to stem strangulation and girdling treatments, to the application of nutrients, to mulching and to pruning of the crown so that suitable methods can be devised of converting A or Plus woodlands into good seed production units.

Finally the effects are being tried of different rootstocks, of root pruning, manurial treatments and disbudding on the flowering of clones of Plus trees produced by grafting. The object is to prepare the way for the management of future tree seed orchards.

Cross-pollination work has been extended slightly during the spring of 1952, but as in past years the greatest effort was directed towards the selection and propagation of suitable material for future use.

Reports by Species:
Corsican Pine

Seed Sources

The register of seed sources of this species now includes some eighty entries totalling over 1,400 acres. Table 28 gives an area statement of the A or Plus and B or Normal stands by age-classes and site types. It will be seen that the distribution is weighted heavily in favour of the younger age classes, the area of stands of over forty years of age being very small. The search for suitable seed sources in these age-classes continues.

PLUS AND NORMAL SEED SOURCES FOR CORSICAN PINE

Table 28 — Area in acres arranged by geographical distribution and age classes.

Distribution & Geology	Principal Forests with Seed Sources	25-30 Years		31-40 Years		41-60 Years		61-100 Yrs.		Total
		Plus	Normal	Plus	Normal	Plus	Normal	Plus	Normal	
Norfolk & Suffolk (mainly Brecklands of East Anglia)	Rendlesham		56	80						136
	Tunstall	40								40
	Thetford Chase		303			6	12			321
	Swaffham		15							15
	Totals	40	374	80		6	12			512

[*Continued on next page*

Table 28—
continued Area in acres arranged by geographical distribution and age classes.

Distribution & Geology	Principal Forests with Seed Sources	25-30 Years		31-40 Years		41-60 Years		61-100 Yrs.		Total
		Plus	Normal	Plus	Normal	Plus	Normal	Plus	Normal	
Hampshire & Berkshire (mainly Bagshot Beds)	Bere								35	35
	Bramshill		25							25
	New Forest				5			5	2	12
	Totals		25		5			5	37	72
Hampshire (Upper Greensand)	Alice Holt		50	5	15		15		2	87
Sussex & Kent (Hastings Beds)	Gravetye						5			5
	Bedgebury		5							5
	Totals		55	5	15		20		2	97
Cheshire, Notts. Staffs, Lincs. (New Red Sandstone).	Delamere		5	80		15	22			122
	Clipstone	200	30		15					245
	Sherwood						11			11
	Cannock	70	142							212
	Laughton	110								110
	Totals	380	177	80	15	15	33			700
Gloucester (Carboniferous)	Dean Forest....		3							3
Lancashire (Sand Dunes)	Ince Blundell Estate, Formby		20							20
Morayshire (Sand Dunes)	Culbin		1				34			35
	Totals		24				34			58
Grand Total of Seed Sources		420	655	165	35	21	99	5	39	1,439

The number of plus trees has been increased to sixty by selecting twenty more trees of over sixty years age. A new trial of progeny arising from the free pollination of these trees was sown in the spring of 1952.

Stimulation of Flowering and Fruit Production

The results of a trial of methods of increasing the production of cones in a twenty-year-old plantation have been reported in *Forest Record No.* 12, 1951, entitled *Girdling or Banding as a means of Increasing Cone Production in Pine Plantations*, in which it was shown that such treatments significantly increased the cone production of trees in a twenty year old plantation of Corsican pine. The treated trees have been under continuous observation during the year, and in January, 1952, all the ripened cones were collected. The seed was extracted and sown at the end of February.

The seed from five sample trees was tested by the seed laboratory. All the trees included in this test were in the same girth class and had been treated at the same time i.e. September, 1948. The test indicates that the strangulation and girdling treatments have not reduced either the size or the viability of the seed tested. The germinative energy of the seed was high, the germination percentage after twenty days on the Copenhagen tank ranging from sixty-seven to ninety-seven per cent.

The health and vigour of the majority of the treated trees in the experiment has not yet been affected. Three trees which died had all been subjected to the complete girdling treatment. Twenty per cent. of the seed from one tree was destroyed during storage by larvae of the moth *Ephestia elutella.*

Of the 180 trees in the experiment, seventy-five, mainly in the lower girth classes, did not bear seed. The remaining trees yielded thirteen pounds nine ounces of seed, one pound three ounces from eighteen untreated trees and twelve pounds six ounces from eighty-seven treated trees. The smallest girth class produced two ounces of seed, and the largest girth class five pounds thirteen ounces or forty-three per cent of the total yield. Had the collection been restricted to the dominant trees of good form, the yield of seed would have been between six and eight pounds per acre. Progeny of over one hundred trees from this cone induction experiment are now developing in the agricultural type nursery at Alice Holt. Their growth as one-year seedlings, and subsequently as transplants, will be compared with that of the progeny of one of the largest and best formed untreated trees in the same plantation.

It has been suggested that strangulation and girdling, and similar methods of stimulating cone production in young plantations, favour the collection of seed from trees which tend towards abundant cone production and poor vegetative growth. For the present, until more is learnt about the effects of these and allied treatments, the technique will only be applied in seed stands after the removal of all obviously unsuitable trees, and in areas such as the Midlands of England where seed production is normally rather low. Strangulation and girdling may not be necessary in East Anglia or South Eastern England.

Eighteen acres of seed stands were marked during 1951, the bulk of them in the Midland counties of England. One acre has already been heavily thinned and underplanted. The standard layout adopted consists of strips one or two chains wide around the wind-firm periphery of the plantations. Up to 250 potential seed trees per acre are permanently marked, and the stand is then heavily thinned in one or more stages to favour these. Subsequently underplanting, manuring and mulching treatments are to be used where necessary to maintain the health and seed production of the seed stands.

The bulk of the future seed supplies of Corsican pine will probably come from tested or Elite seed stands. A relatively small area of seed orchard will be established, so that the early well-tried introductions of Corsican pine can be fully utilised. The area of plantations over eighty years of age is small, but their value as seed sources is very great.

Propagation by Grafting

The first species chosen for intensive study at Grizedale was Corsican pine, and over six hundred grafts were attempted with the ultimate objects of producing clones for a trial of rootstocks and a trial of the genotype at Alice Holt. The conduct of the propagation study and the results obtained are now described.

Preparation of the rootstocks. Sturdy seedlings and transplants up to twelve inches tall of Scots pine (Ident. No. 48/188, Origin Altyre, Morayshire), *Pinus contorta* (Ident. No. 49/55, Origin British Columbia) and *Pinus mugo* (Ident. No. 48/1020, Origin France) were potted into six-inch pots during the winter of 1950. The growth medium used was John Innes potting compost, without the addition of lime.

In August, 1951, the rootstocks were put under glass at Grizedale. The propagation beds were prepared with basal drainage and a half-and-half mixture of sand and peat, into which the pots were fully plunged. The beds were heated to 55°F. by a low voltage electrical soil heating system, those in House No. 1 being heated from mid-January, 1952, and those in House No. 2 from mid-

February. In House No. 1 the roots of the potted plants became active towards the end of January. Shoot growth began in both houses during the latter part of February.

Collection of the scions. The scions were collected during December, 1951, and January and February, 1952. Branches eighteen inches to two feet long were taken from the upper parts of the crowns of selected Plus trees bearing a number of sturdy well-ripened one-year shoots of good but not excessive vigour. The one exception was the material collected at Rendlesham Forest (Suffolk); scions had been collected from five Plus trees in 1950, and strong regrowth was available on the shortened branches; this was taken for grafting but proved unsuitable.

Collection was by climbing in younger trees, or by shot-gun in trees over sixty feet tall. The branches were packed in a framework of wire mouse netting covered with hessian and sent by post to Grizedale. On arrival the parcels were put into a cool room until required. The time elapsing between collection and grafting was rarely more than one week.

The grafting method. The veneer side graft was chosen as the standard method. Preliminary studies at Alice Holt, indicated that a deep cut on the root-stock, extending about one third across the diameter of the stem, resulted in a useful reduction of resin flow. The basal notch which is part of the veneer side graft was accentuated, since past experience indicates that much depends on the accuracy of the union at this point both for early callus formation and to reduce drying out of the scion. All scions were taken at the junction of one-year and two-year wood. Plates VI, VII, and VIII illustrate the method and the results obtained.

Four variations were introduced into the treatment of the scion. The foliage of all the scions was reduced to twelve to fifteen pairs of needles clustered around the base of the bud. Then the remaining needles were either left intact or shortened by half, the cut ends being sealed with low-melting-point paraffin wax. The cut on the scion was made either from the base to just below the leading bud, or was confined to the lower half of the scion. The graft union was waxed completely in both cases; thus the scion was either completely protected or only half protected from moisture losses. Tying was by raffia throughout, and a narrow band of raffia was left unwaxed on the stem of the rootstock opposite to the point of grafting, so that the pressure due to callousing could be easily seen and quickly relieved.

Assessments. Grafting commenced on 12th December, 1951, and continued until 27th February, 1952. The condition of rootstocks and scions have been continuously recorded, and the propagation conditions were carefully controlled, in particular the maximum possible amount of sunlight being admitted to the houses. All the grafts were made by one experienced man with assistance to carry scions and apply the grafting wax.

The results of the first assessment are summarised below, only strongly developing grafts being included. The effects of different speeds of heading back the rootstock are to be studied, and the subsequent performance of the grafted plants will be continuously observed for five years. Particular attention will be paid to the strength of the graft union, and the effects of the root-stocks on the growth and flower production of the scions.

A few grafts were made using the whip-and-tongue method, as this has already proved useful for Corsican pine. The previous success was repeated at Grizedale.

Summary of Results

(1) *Pinus contorta* (49/55) rootstocks began growth before the other two,

and the number of successful grafts was correspondingly higher at the first assessment. Scions on *Pinus mugo* (48/1020) were noticeably the slowest in development.

(2) The long cut on the scion, combined with complete waxing and the reduction of the remaining foliage, has given promising results, and over three quarters of the grafts are developing strongly. The shorter veneer combined with non-reduction of the terminal rosette of needles has given poorer results, and less than one quarter of the grafts attempted are developing satisfactorily.

(3) There is a good correlation between the type of scion material collected and its subsequent performance. The very vigorous regrowth material from thirty year old trees at Rendlesham (Suffolk) proved unsuitable (eighteen per cent success). The sturdy and vigorous one year wood from twenty-five year old trees at Laughton (Lincolnshire) gave eighty-eight per cent success. Similar but less vigorous material from fifty year old trees at Bere (Hampshire) and Delamere (Cheshire) gave respectively sixty-six per cent and fifty-six per cent success.

(4) Provided the rootstocks are well established, i.e. have had one full season in pots, Corsican pine can be successfully grafted under glass during December. Speedier results are obtained if the rootstocks are growing vigorously at the time of grafting, and for this reason January and February are more suitable months for spring grafting under glass.

Spring grafting out of doors. The intention is to apply the best methods evolved at Grizedale to large-scale grafting on transplants in the open nursery. The most successful method of long veneer and drastic reduction of the foliage of the scion, combined with very complete protection of the scion and graft union by waxing, has been applied on a small scale in the arable nursery at Alice Holt. The results are encouraging, the success at the time of writing being over fifty per cent.

Beech

Seed Sources

The register of seed sources for this species now includes thirty-four classified entries totalling over 1,000 acres. Table 29 gives an area statement of the A or Plus and B or Normal stands by age-classes and geographical distribution. It is expected that the number of seed sources in Scotland will be increased when the survey of that country is extended to include the counties of Roxburgh, Ayrshire, Berwickshire and Dumfries.

PLUS AND NORMAL SEED SOURCES FOR BEECH

Table 29 — Area in acres arranged by geographical distribution and age classes

Distribution	Principal Estates With Seed Sources	81-120 Yrs.		Over 120 Yrs.		Totals
		Plus	Normal	Plus	Normal	
Gloucester (The Cotswold Hills)	Kingscote and associated estates		62	61	40	163
	Cirencester Park		13	9		22
	Badminton				50	50
	Totals		75	70	90	235

[*continued on next page*

Table 29—*continued*

Area in acres arranged by geographical distribution and age classes

Distribution	Principal Estates With Seed Sources	81-120 Yrs.		Over 120 Yrs.		Totals
		Plus	Normal	Plus	Normal	
Sussex & Hampshire (The South Downs)	Goodwood	176			98	274
	West Dean				79	79
	Slindon			56		56
	Cowdray Park (Mellersh Copse)		18			18
	Ashford Chase				5	5
	Totals	176	18	56	182	432
Buckingham (The Chiltern Hills)	Penn Woods		382			382
Wiltshire	Maiden Bradley				2	2
Yorkshire	Castle Bolton		4			4
Northumberland	Nunwick Park				15	15
	Totals		4		17	21
Morayshire	Westfield Farm, Nr. Elgin		9			9
Grand Total of Seed Sources		176	488	126	289	1,079

The first trial of the genotype for beech has been established on the agricultural type nursery at Alice Holt. This tree display consists of clones of grafted plants from thirty Plus trees, arranged in parallel lines across three sections of the nursery. Normal nursery operations will continue while the grafted plants are developing. The layout is such that the tree display can eventually be converted into an experimental beech seed orchard.

Each of the trees in the trial of the genotype are represented in a progeny trial in which the progeny from the best known stands and single trees in this country are being compared with progeny from plantations in many parts of Europe. The field trials of these various origins are to be managed by the Silvicultural section.

Propagation by Grafting

A number of five-year-old beech have been planted to provide rootstocks for a trial of top-working methods. The grafts will be made at six to twelve feet from the ground, and the resulting trees will be pruned to stimulate the development of large rounded crowns as quickly as possible.

Larches

A trial of the genotype involving ten Plus trees was planted at Drummond Hill Forest, Perthshire. The establishment of the first seed orchard for the production of first generation hybrid larch began at Newton Nursery, Elgin, during the spring of 1952. This orchard will be four acres in extent and will contain clones of twelve Japanese larches and three European larches.

The propagation of the larches from cuttings continued to receive considerable attention throughout the year at two centres in Scotland and two in England. Attack by *Botrytis* spp. on both dormant and summer wood cuttings hampered progress considerably.

Scots Pine

A trial of the genotype involving grafts from ten Plus trees selected from four remnants of the old Caledonian Forest was planted at Torrie Forest, Perthshire.

Sitka Spruce

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

ESTABLISHMENT OF POPLARS

By J. JOBLING
Assistant Silviculturist

Brief mention was made in the *Report on Forest Research* for 1952, of the 1951 experiments, on which assessments were carried out at the end of the first growing season. The assessments were concerned mainly with the survival and health of the trees during the season, as it is on these two factors that the ultimate establishment of a plantation depends. Whilst height growth was also assessed, less importance is attached to this character, as it is thought that increase in height during the first season is only slightly affected by a planting treatment.

Summary of Establishment Experiment

This experiment, designed to show which treatments given to the trees at the time of planting are the most effective for the successful establishment of poplar plantations, has been repeated on three different types of site; at Harling, Thetford, on alkaline fen peat over sand; at Hockham, Thetford, on a sandy loam with high humus content over sand, and in Alice Holt forest on a medium to heavy clay soil which had previously borne a coppice crop with standards. Both the Thetford sites have a high water table and readily available soil moisture. The age and types of planting stock used are one-year rooted cuttings, stumped one-year cuttings lined out in the nursery for one year, stumped one-year cuttings lined out for two years, and unrooted sets; the varieties under observation are *Populus serotina*, *P. serotina* narrow-crowned variety, *P. gelrica* and *P. robusta*. At each site there are forty-eight plants per variety of each age or type, except with stumped one-year cuttings lined out for two years which are represented by *P. serotina* narrow-crowned variety only on all three sites, and by *P. gelrica* at Harling only. A mulch, mound or one of two levels of a potash-phosphate fertiliser was applied to the trees at the time of planting, either singly or in combination with other treatments; this fertiliser is potassic superphosphate, (Fisons No. 7) applied at the rate of 6 oz. or 12 oz. per plant.

The experiment was laid down to compare the behaviour of the four types of plant to the different treatments rather than to compare the differences between the varieties, but it is interesting to note that *P. serotina* narrow-crowned variety and *P. gelrica* survived better on all three sites than the other two varieties. There were considerable differences in the survival of the types of plant on any site, the table below giving comparative figures.

FIRST-YEAR LOSSES AMONG FOUR DIFFERENT TYPES OF POPLAR PLANTS

Table 30 Planted Spring, assessed autumn, 1951

Variety	Percentage of deaths											
	Harling				Hockham				Alice Holt			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
P. serotina	15	6	0	–	23	4	0	–	29	2	4	–
P. serotina n.c.v.	4	0	0	0	0	21	2	2	0	0	6	2
P. gelrica	10	0	0	0	0	0	0	0	0	0	0	–
P. robusta	10	6	0	–	10	15	2	–	15	8	0	–

Types of plant:—

T_1 =unrooted sets

T_2 =one year rooted cuttings.

T_3 =stumped one year cuttings lined for one year.

T_4 =stumped one year cuttings lined for two years.

n.c.v. =Narrow-crowned variety.

There were the least number of deaths on any site in the stumped one-year cuttings lined for one year, which also increased in height appreciably more than the other types, whilst sets generally gave the greatest number of deaths. One-year rooted cuttings survived better than either sets or stumped one-year cuttings lined out for two years, and increased in height more than these two types. Stumped one-year cuttings lined out for two years, a large and expensive type of plant to produce in the nursery, were no more successful in the field than the unrooted sets, which are relatively cheap to raise.

The different treatments produced virtually the same results on all three sites. Neither mounding nor mulching had a marked effect on height growth or survival, but the health of the surviving plants was greatly improved in the presence of either treatment. The application of the fertiliser, at either of the two levels, produced very similar results to these but, in addition, they generally raised the average height-increase on any site. The behaviour of plants receiving both a mound and mulch was similar to those receiving only one of the treatments, whilst the beneficial effect of the fertiliser was greatest on plants which were neither mounded nor mulched.

Summary of Manurial Experiment

This experiment is repeated on four sites, at Harling, Hockham and in Alice Holt forest adjacent to the establishment experiment plots, and in Rockingham (Drayton) Forest on heavy Northants boulder clay bearing a dense grass growth. The same four standard varieties have been used, but only stumped one-year cuttings lined out for one year are under observation. The fertilisers were applied at one of two levels, either separately or in combination, with phosphate in the form of superphosphate (8 oz. or 16 oz. per plant) and potash as muriate of potash (4 oz. or 8 oz. per plant) applied at the time of planting, and nitrogen in the form of sulphate of ammonia (4 oz. or 8 oz. per plant) applied half way through the season.

On the whole, the varieties reacted to the treatments in a similar manner, and survival was good throughout, except at Drayton where there were a considerable number of deaths and none of the manurial treatments produced any appreciable effects on either survival or health. The outstanding treatment on the other three sites was the application of nitrogen which, at both levels,

markedly improved the health of the surviving plants and generally raised the average increase in height for all varieties. At Harling, potash produced a similar effect, and it is of interest to note that the beneficial effect of nitrogen on the health of the plants, and on the average increase in height, was shown only in the presence of potash.

Experiments laid down in 1952

During February and March four silvicultural experiments were laid down in the field, and two experiments were started at Kennington nursery on the raising of planting stock from cuttings. In addition, a number of small-scale nursery projects were placed under observation, of which two or three will be extended to full experimental status at a later date.

Two of the field experiments are of the basic establishment type, one is at Harling and the other at Drayton, and to the mounding and mulching treatments has been added complete cultivation of the soil around the plant. It is hoped that by maintaining the area around the plant completely free of weed growth during the growing season, the comparative effects of mulching, and to a lesser extent mounding, can be more closely studied. The experiment at Drayton is of particular interest, in that past attempts at establishing poplar have proved difficult because, it is thought, of the competitive nature of the heavy grass growth for soil moisture during the trees' peak growing period.

A nursery extension experiment laid down at Harling, using one-year rooted cuttings only, is designed to determine the effect of wide spacing in the nursery, with and without root pruning, on the survival and health of the plants when transferred to the field. It has been shown that cuttings inserted at a wider spacing than normal produce an extensive root formation, which when pruned to within six inches of the cutting during its peak growing period produce plants comparable with stumped and transplanted stock in rigidity and shoot height growth, and possess what is thought to be a most desirable fibrous root system. Such plants would seem suitable for the field after only one year in the nursery, and further work of this sort is being undertaken so that confirmative information will become available as soon as possible.

The fourth field experiment is laid down in the North Oakley Inclosure, New Forest, on a soil which is acutely deficient in lime and phosphate and markedly deficient in potash. The experiment is designed to obtain preliminary evidence of the responses of poplar to lime, applied to the soil before planting, and an N.P.K. fertiliser (superphosphate, 16 oz. per plant; muriate of potash, 8 oz.; sulphate of ammonia, 8 oz.) applied during the second season. Sufficient lime has been added to the soil to raise its pH from about 4.2 to over 6.0. (The actual quantity used was 110 cwt. per acre). Two varieties are under observation, *P. trichocarpa* "H.T." and *P. serotina* (narrow-crowned variety) "V.B.", and it is hoped that the relative behaviour of Balsam and Black hybrid poplars to acid soil conditions will become apparent in due course.

The larger of the two nursery experiments is concerned with the wide spacing and root pruning of cuttings; three spacings and two times of pruning are under observation, and the treatments are being carried out on the four standard varieties. The second experiment is devoted to testing the effect the length of cutting has on the survival and growth of the shoot during the season. Six different cutting lengths, ranging from four inches to nine inches, are under observation.

A general impression of the kind of growth obtained in the nursery is given by the view of one-year-old poplars at Alice Holt Lodge, reproduced as Plate X.

The silvicultural experiments on poplar have shown that, during the first season at least, the laying down of a mulch or mound around the plant, or the application of a fertiliser to the region of the plant roots, improves the health of the plant and increases its chances of survival. It is also evident that by applying a fertiliser, height growth is increased, and of those under observation a nitrogenous fertiliser is most likely to produce the best results on a range of sites.

STUDIES OF GROWTH AND YIELD

By F. C. HUMMEL
Mensuration Officer

Sample Plots

Numbers of permanent sample plots established, remeasured and abandoned during the year are shown in Table 31.

Table 31 NUMBERS OF SAMPLE PLOTS, 1951-1952

	England	Scotland	Wales	Total
Plots in being 1st April, 1951	203	192	63	458
Plots established 1.4.51 to 31.3.52	13	16	18	47
Plots written off	Nil	7	Nil	7
Plots in being 31st March, 1952	216	201	81	498
Plots remeasured 1.4.51 to 31.3.52	9	70	54	133

Of the 47 new plots, 13 were in England, 16 in Scotland and 18 in Wales. All the new plots have been thinned to the standard grade appropriate to the species, the main object being to add to our knowledge of the rate of growth of the more commonly grown species in Britain under a standard thinning treatment and over the range of sites over which they are usually planted. A subsidiary object was to provide demonstrations of these thinnings at convenient sites. Ten of the new English plots are in Mortimer Forest in Shropshire, two in the Thetford Chase area in Norfolk and one in Wyre Forest, Worcestershire. All the new Scottish plots are North of the Caledonian Canal in forests where many plantations are reaching the thinning stage, but there are as yet few sample plots. Most of the new Welsh plots were established in experimental areas which are of silvicultural as well as purely mensurational interest. Eight of the plots are in the high elevation experiment at Beddgelert, where there are plots of several species established in the form of a latin square, extending up a hill in order to test the effect of elevation and exposure on the growth of these species. Four plots were established in a Scots pine spacing experiment at Tintern in Monmouthshire. Three of the plots are on Mr. Ackers Estate at Leighton Park near Welshpool in Montgomeryshire. The first is a particularly fine hybrid larch plot the seed for which had been collected from the European

parent, the second a European larch plot descended from the same parent trees, and the third a plot of *Sequoia sempervirens*, which at an age of 16 years has already produced 3,900 hoppus feet over bark per acre. Two thuya plots at Gwydyr and Corris (Dovey Forest) and a Japanese larch plot at Clocaenog complete the list of establishments.

Among the 133 plots remeasured during the year, the following deserve to be specially mentioned: Douglas fir plot E.19 at Tortworth in Gloucestershire which, at 82 years, has reached a top height of 130 ft., and during the past ten years has averaged an annual volume increment per acre of 130 hoppus feet over bark; the 94 year old *Sequoia sempervirens* plot at Leighton Park which has a standing volume of 24,000 hoppus feet per acre, of which the bark accounts for nearly one third; and the Douglas fir plots S.37 and 38 on Lord Lovat's estate at Beaufort, Inverness, which at 45 years have top heights of 104 and 102 ft. respectively.

The severe gales in January, 1952, took a heavy toll of the sample plots in Scotland. Seven plots, including some of long standing, had to be abandoned completely, and less severe damage occurred in another twenty-five plots. These losses are the severest for many years, and have naturally called for a re-examination of the factors which contribute to the incidence of wind blows. A preliminary and superficial survey of the damage to the plots and the surrounding stands suggests that local topography and drainage may be more important than thinning treatment, and that the forester's main defence against gales lies in the correct choice of species or mixture of species, and careful attention to drainage. There is, however, some evidence to support the widely held view that stands which are thinned heavily right from the start may be slightly more wind-firm than stands that have been thinned lightly or not at all. Heavy thinnings in stands that have been lightly thinned in the past inevitably invite disaster.

In addition to the permanent sample plots, 339 temporary sample plots were measured in broadleaved species. Their distribution by Conservancies and species is shown in Table 32.

TEMPORARY HARDWOOD SAMPLE PLOTS

Table 32 Established between 1.4.51—31.3.52 inclusive

Conservancy	Total	Oak	Beech	Ash	* Other hardwoods
S.E. England	18	7	4	3	4
S.W. England....	23	6	—	8	9
East England	45	13	5	7	20
N.W. England	11	4	—	—	7
Dean	10	10	—	—	—
New Forest	10	10	—	—	—
South Wales	42	22	7	10	3
North Wales	81	49	15	7	10
N. Scotland	9	4	3	2	—
S. Scotland	42	9	23	—	10
E. Scotland	25	12	10	—	3
W. Scotland	23	12	5	—	6
Total	339	158	72	37	72

*Other hardwoods include birch, elm, sycamore, sweet chestnut, Black Italian poplar, lime and alder.

Yield Tables and Volume Tables

The temporary sample plots measured in 1950 and 1951, together with stem analyses of individual trees and the limited records from permanent sample plots, provide the basis of the provisional yield tables for oak, beech, ash and sycamore which are being prepared. The "height over age" curves by quality-classes have been completed, and are reproduced in Figures 2 to 5. The quality-classes are based on top height at an age of 50 years, and the height interval between quality classes is 10 feet at that age, just as it is in the new conifer yield tables. Top height is defined as the average height of the 100 largest trees per acre. In both oak and beech the new British curves for the first quality class indicate a faster rate of height growth in early life than the Danish and German yield tables, but later the position is reversed, so that the ultimate height on first-quality sites in this country appears to be similar to that on equivalent sites in Western Europe.

Good progress has also been made with the revision of the existing conifer yield tables; those for Douglas fir, Sitka spruce and Norway spruce are complete, while work on European larch, Corsican pine and Scots pine is well advanced. The demand for quick and simple methods of estimating future production in Forestry Commission plantations has added to the urgency of completing these tables. The new tables differ from the old ones in two main respects. First they show a slightly lower total volume production and secondly they are based on a much heavier thinning regime which accords more closely with current practice. Minor differences in form rather than in content are that the new tables are based on "top height" instead of mean height, and that they show hoppus volumes over bark instead of under bark.

FIG. 2.

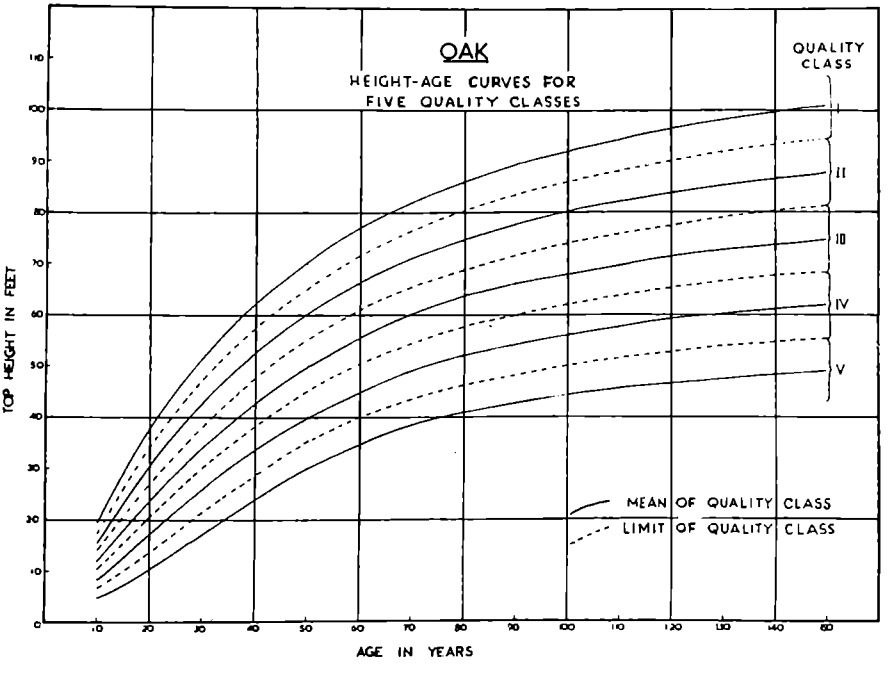


FIG. 3.

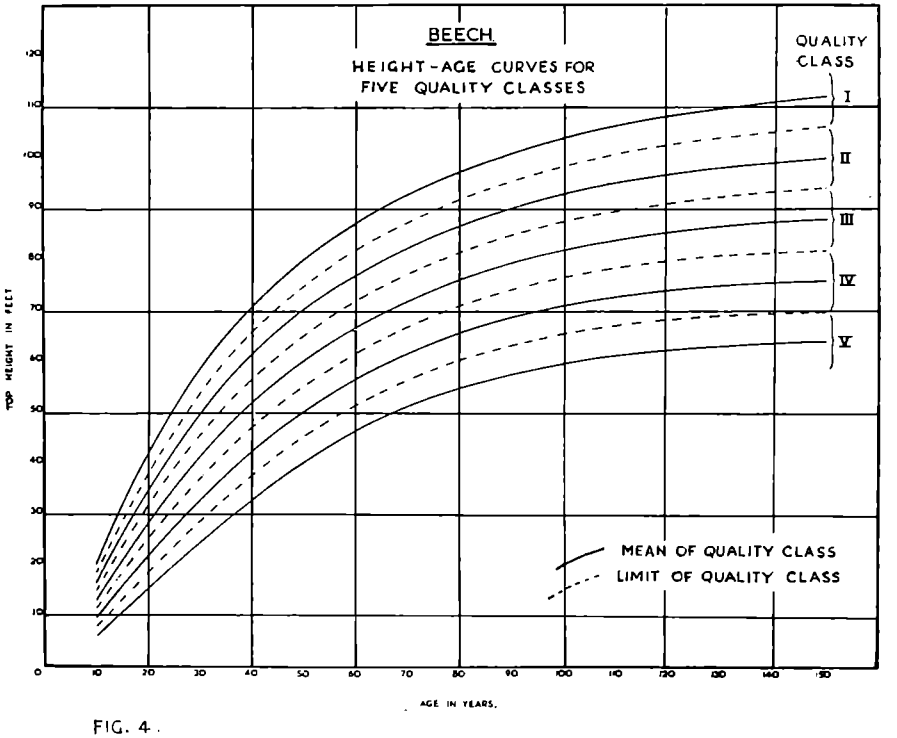

BEECH
HEIGHT-AGE CURVES FOR
FIVE QUALITY CLASSES
QUALITY
CLASS
I
II
III
IV
V
MEAN OF QUALITY CLASS
LIMIT OF QUALITY CLASS
TOP HEIGHT IN FEET
AGE IN YEARS.

FIG. 4.

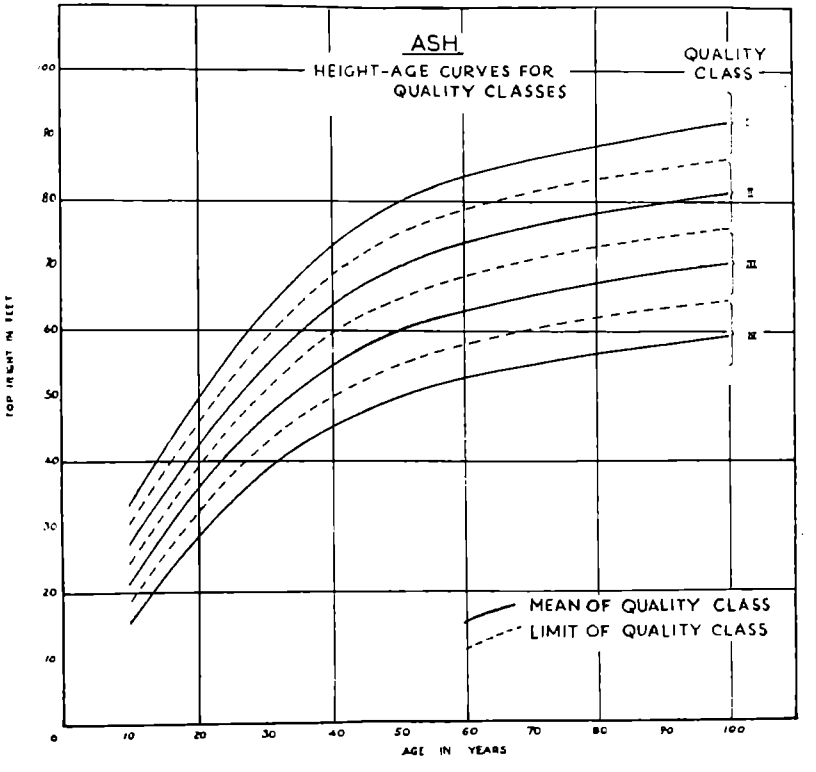
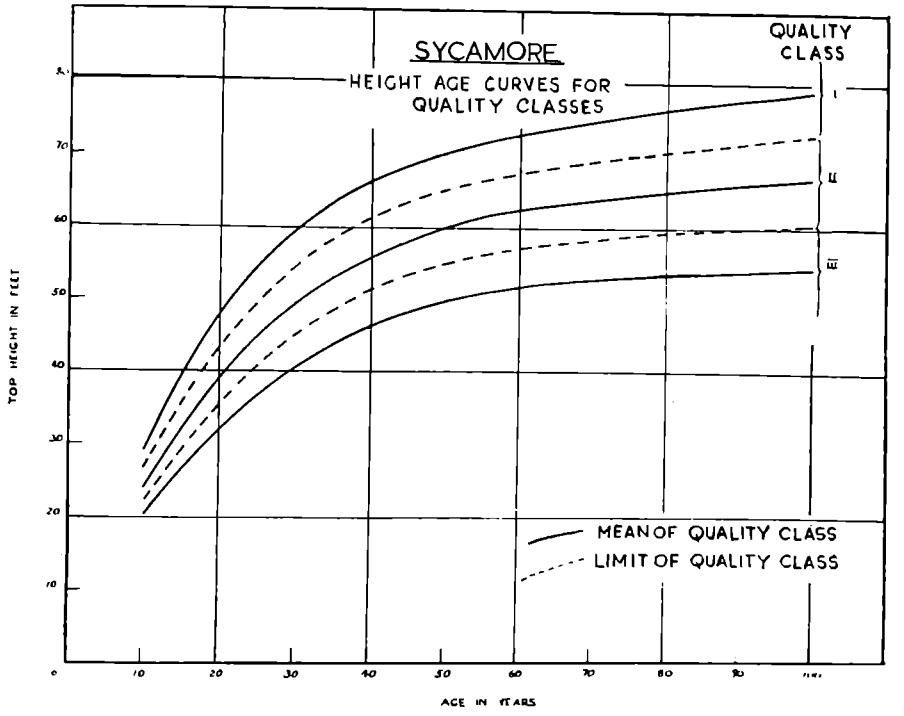

ASH
HEIGHT-AGE CURVES FOR
QUALITY CLASSES
QUALITY
CLASS
MEAN OF QUALITY CLASS
LIMIT OF QUALITY CLASS
TOP HEIGHT IN FEET
AGE IN YEARS

FIG. 5.



The general volume tables for Japanese larch and Douglas fir were completed and published as Forest Records Nos. 14 and 15. A special volume table for determining the volumes of early thinnings in the Scots and Corsican pine plantations of East Anglia was prepared from data supplied by the Eastern Conservancy. The tables are based on butt diameter instead of breast-height diameter, and on length to 1½ inch diameter instead of total length. The poles are cut, extracted and stacked according to the size classes differentiated by the volume table. Usually this can be done by eye, and a reasonably reliable estimate of volume is obtained with very little measuring. The method has proved satisfactory in practice under the conditions for which it was designed, but it is not applicable when an estimate of volume is required before the trees are felled.

Estimates of "Small Wood" Production

While it has been customary in most areas to utilise and measure conifer thinnings to a top diameter of 3 inches over bark, markets are gradually developing for "small wood" between 3 inches and 1½ inches in diameter, and estimates of the amount of material in this size class which is likely to be available over a long term of years are sometimes called for. The preparation of such estimates may be facilitated by a fact which emerged from an analysis of data from some 1,800 temporary 1/10th acre plots which had been measured by the local forest staffs during the past few years; it was found that the average volume of small wood per tree amounts to about ¼ of a hoppus foot over-bark, in all the species examined, in first as well as in subsequent thinnings. Thus a first thinning operation removing 400 trees per acre might be expected to yield 100 hoppus feet of small wood, and a second or third thinning removing 200

trees about 50 hoppus feet. Individual trees of course may differ widely from these averages.

Use of the "Volume/Basal Area line" for Determining Standing Crop Volumes

A study of the relationship between the volume of trees in a stand and their sectional areas at breast-height has produced results which may be of practical use in forest enumerations. It has long been known that in a coniferous stand this relationship between volume and breast-height sectional area is usually linear. Examination of the permanent sample plots records has shown that the point where the line intersects the x axis (or abscissa of the graph) remains more or less constant at 0.03 square feet although the slope of the line increases with age. A table was prepared giving for every quarter-inch girth class the volumes as read from a series of these lines, all going through the common point on the x axis and having vertical intervals equivalent to 1 hoppus foot at a basal area of 1 square foot. If the volumes of a limited number of sample trees in a stand are known, it is possible to determine which column in the table best fits the data, and this column may then be used as a local volume table. The main advantages claimed for this method of volume determination are that: first, there is no need to determine the mean girth of the stand before selecting the sample trees; second, the sample trees need not be of a specified girth, provided they reasonably cover the range of girth in the stand; third, not only an estimate of the total volume but of its distribution by girth classes is obtained. The practical details of how the method can best be applied in the field are being investigated.

Yield of Hazel Coppice

Hazel is the main coppice species in 131,000 acres of coppice and coppice-with-standards in Great Britain. Most of this is found in the Southern counties on comparatively fertile sites, but little appears to be known of its stocking and its rate of growth. On behalf of the Utilization Development Committee experiments were carried out in order to obtain some preliminary information on these points. 51 one-tenth acre plots of hazel coppice from six different sites were felled. The produce was weighed and its moisture content and specific gravity were determined. On three of the sites the coppice had been properly managed and cut on a regular rotation, while on the other three the coppice had been unworked for a long period of years. The maximum green weight of produce was 25 tons per acre (at 75% moisture content); this was in on e of the unworked areas which generally gave a greater weight than the worked areas, which latter were much younger and showed a higher mean annual increment. The specific gravity of the oven-dry material ranged between 0.63 and 0.71. The analysis of the data has not been completed.

Effect of Site on Timber Quality

The effects of site and silvicultural measures on the development of the growing stock have been studied in our permanent sample plots for many years, but comparatively little is known of how these factors affect the quality of the timber. The Forest Products Research Laboratory at Princes Risborough and the Research Branch of the Forestry Commission have jointly embarked upon a long-term investigation which is designed to throw some light on this subject. As a start comprehensive strength tests were carried out by the Forest Products Research Laboratory on twenty trees of Japanese larch from our permanent sample plots at Stourton in Wiltshire, while density determinations were carried out on material from three Sitka spruce plots in Wales.

Statistical Methods

The work of the Statistical Section has continued in two main directions: first, general computational work and the design and analysis of experiments for the various sections of the Research Branch and secondly, the preparation of papers which are intended to give foresters elsewhere the benefit of what we have learnt. The completion of the general volume tables, the preparation of the special volume table for East Anglian pine referred to previously, a preliminary study of the relationship between crown diameter and breast-height diameter in sycamore, and the analysis of 72 experiments were the main tasks undertaken.

FOREST PATHOLOGY

By T. R. PEACE
Forest Pathologist

During the year comparatively little work has been done on the main lines of research that can aptly be included in an annual report. This does not mean that no progress has been made, but rather that the nature of the work, or the stage which it has reached, are such that it cannot easily be written up in a summarized form. For instance the investigations on "group-dying" of Sitka spruce, and on "top-dying" of Norway spruce have reached the stage where experiments have been laid down, which should yield useful information in a year or two. If these do not solve the problem, they will at any rate narrow the field of research into its causes. Work on bark dieback and canker of beech has brought to light a number of fungi, which are now the subject of inoculation tests. A further year's data on the occurrence of *Phaeocryptopus gäumannii* on the needles of Douglas fir has been collected, but it has little meaning till the analysis of all the data collected over the past five years has been completed. Efforts to control *Botrytis cinerea* on coniferous nursery stock again failed. Treatment of coniferous seed with fungicides has given promising results, which, however, require confirmation.

Thus any attempt to review the year's work would merely be a catalogue of uncompleted tasks. It seemed, therefore, that some worthwhile information might result from an analysis of the numerous enquires that reach the section, to see what light they throw on the problems causing most concern in the field. During the year the section dealt with 148 enquiries, which can be broken down as under:—

	Pathology	*Poplar Cultivation and Diseases*	*Total*
Private Estates	64(19)	44(10)	108(29)
Forestry Commission	37(9)	3(1)	40(10)
Total	101(28)	47(11)	148(39)

Figures in brackets indicate the number of enquiries which involved visits.

Ninety-seven of the pathological enquiries are analysed in Table 33 below. It will be noted that comparatively few of the enquiries relate to diseases

ANALYSIS, BY NATURE OF DISEASE AND SPECIES OF TREE AFFECTED, OF ENQUIRIES DEALT WITH BY THE PATHOLOGICAL SECTION, 1951-1952

Table 33

	Armillaria mellea	Botrytis cinera	Miscellaneous Fungal Diseases	Specialized Diseases	Decay	Soil Water Relations	Soil Nutrient Deficiencies	Wind	General Enquiries	Unexplained Causes	Total
Conifers											
Scots pine....	2	—	1	7 (Leaf Cast)	—	1	—	—	—	2	13
Corsican pine	—	—	—	3(,, ,, & Dieback)	—	—	—	—	—	—	3
Pinus insignis	—	1	—	1 (Leaf Cast)	—	—	—	—	—	—	2
European larch	—	—	—	—	2	3	—	—	—	—	5
Japanese larch	—	1	—	—	—	1	—	—	—	1	3
Hybrid larch	—	—	—	—	—	1	—	—	—	—	1
Douglas fir	1	1	1	—	—	3	—	1	—	1	8
Norway spruce	1	—	2	4 (Chrysomyxa)	—	2	2	—	2	1	14
Sitka spruce	—	—	—	2 (Group Dying)	—	—	—	—	—	—	2
Lawson Cypress	1	1	—	—	—	—	—	—	—	—	2
Western Red Cedar	—	—	—	2 (Keithia)	—	—	—	—	—	1	3
Yew	—	—	—	—	1	—	—	—	—	1	2
Juniper	—	—	1	—	—	—	—	—	—	—	1
Cedar	—	1	1	—	—	—	—	—	—	—	2
Conifers mixed	—	2	—	—	1	—	—	—	—	—	3
Total Conifers	5	7	6	19	4	11	2	1	2	7	64

[*Continued*

Table 33—*continued*

	Armillaria mellea	Botrytis cinerea	Miscellaneous Fungal Diseases	Specialized Diseases	Decay	Soil Water Relations	Soil Nutrient Deficiencies	Wind	General Enquiries	Unexplained Causes	Total
Hardwoods											
Oak	—	—	—	1(Mildew)	—	—	—	—	—	—	1
Ash	1	—	—	1(Bacterial Canker)	—	—	—	—	—	1	3
Beech	1	—	2 (Bark die-back)	—	2	—	—	—	—	1	6
Sycamore	—	—	—	3 (Sooty bark)	—	2	—	—	—	—	5
Spanish Chestnut....	—	—	1	1 (Ink disease)	—	—	1	1 (Broken shoots)	—	—	4
Walnut	—	—	—	—	—	—	—	—	—	2	2
Willow	—	—	1	2 (Scab)	—	—	—	—	—	—	3
Plum	—	—	1	—	—	—	—	—	—	—	1
Elm	—	—	—	3 (Elm Disease)	—	—	—	—	—	—	3
Lime	—	—	1	—	—	—	—	—	—	—	1
Horse Chestnut	—	—	1	—	—	—	—	—	—	1	2
Tulip Tree	—	—	—	—	—	—	—	—	—	1	1
Total Hardwoods	2	—	7	11	2	2	1	1	—	6	32
Mixed Hardwoods & Conifers	1	—	—	—	—	—	—	—	—	—	1
Grand Total....	8	7	13	30	6	13	3	2	2	13	97

on which the section is working actively, such as "group-dying" of Sitka spruce, "top-dying" of Norway spruce, bark dieback of beech, or needle casts of Douglas fir. This is certainly partially due to the fact that in the course of the work many of the people, who would otherwise have enquired about their trees, were visited and the disease explained to them verbally. Other learnt about the diseases from these people at second hand, and the number of enquiries was further lessened. In most cases the existence of a Forestry Commission Leaflet or other publication on a disease cuts down the number of enquiries, especially if diagnosis is fairly easy, as it is for instance with Elm Disease or Watermark Disease of willow.

In general it will be noticed that about twice as many enquiries relate to conifers as to hardwoods, and the disproportion would be larger, were it not for the fact that a number relate to amenity trees, in which category hardwoods are more important.

Armillaria mellea (Honey Fungus)

This parasite, though seldom catastrophic, is very generally distributed, and every year we receive a number of enquiries about it. None of the outbreaks reported were particularly serious, but several were of particular interest. In one case it was killing poor-quality ash coppice in an ever widening circle, but so slowly that young conifers planted in the centre (now about an acre in extent), after the ash had died, are now shoulder high. In another case Honey Fungus had been spreading unrestricted in a neglected garden, and had killed cedars, a yew, a weeping willow, a quince, a plum, some lilacs, and probably other trees. Since nothing had been felled or removed till quite recently, it was using each tree, as it succumbed, as a base for attack against the next.

Botrytis cinerea in Nurseries

This fungus is normally confined to conifers, but as will be seen from the list covers a wide range of species. As was mentioned above, no success has yet attended spraying experiments against this fungus, so that, although the disease is very easy to diagnose, it is difficult to know what advice to give to enquirers, except the somewhat limited comfort that most conifers recover from attack.

Miscellaneous Fungal Diseases

This includes a number of cases where it has been possible to find a fungus which might be responsible for the damage, but it does not necessarily indicate that fungal injury was definitely proved. None of the fungi recorded was of outstanding interest.

Specialized Diseases

Under this heading are included diseases well known on and specific to certain hosts. All but one of the records of leaf-cast on pines refer to *Lophodermium pinastri*, (the exception was *Hendersonia acicola*). Possibly because of the very wet periods that have occurred, *Lophodermium pinastri* and other leaf-cast fungi seem to have been exceptionally active during the last two years, both in nurseries and plantations.

It is probable that more enquiries would have been received about browning and dieback of Corsican pine, but for the fact that this trouble is known to be the subject of a fairly widespread investigation. This at present has led to the conclusion that the main trouble has been the planting of Corsican pine in unsuitable places, where it is weakened and becomes prone to attack by a large variety of fungi.

It is surprising, considering how much publicity has been given to Chestnut Blight (*Endothia parasitica*), that only three enquiries about suspected cases came in, all of which had simple and much less dangerous explanations.

The widespread occurrence of the rusts *Chrysomyxa abietis* and *C. rhododendri* in Scotland is of considerable interest. It is possible, since they have attracted much less attention in the past, that their importance this year is only a transient phenomenon.

The "group-dying" of Sitka spruce would probably have occasioned more enquiries if Mr. Murray's and Mr. Day's work had not already brought it to such general notice.

Only three enquiries were received about suspected cases of Sooty-bark Disease of sycamore (*Cryptostroma corticale*). Only in one case was the tree found to be attacked by that fungus, the others being caused by superficially somewhat similar, but saprophytic fungi, fruiting on dead limbs. The one report of Ink disease (*Phytophthora*) on *Castanea* was sent in, because of the possibility of its being *Endothia parasitica* (Chestnut Blight). Considering how common Ink disease is in chestnut coppice, particularly on the more intractable parts of the Hastings beds in the south-east, it is surprising how seldom it is reported. Presumably this is because it has no obvious symptoms other than the death of the stools, which are usually assumed to have died of old age.

Surprisingly few reports were received about Elm Disease. There are probably two reasons for this. It is now so well known and the symptoms are so definite, that comparatively few people need expert advice. Also 1950 had a wet summer, resulting in a decrease in the population of infected *Scolytus* beetles in the early summer of 1951, (*Scolytus* beetles are the main means of dissemination of the fungus causing this disease); and this consequently reduced the number of infections for that year. In addition the comparatively wet and cool summer of 1951, meant that the development of symptoms, in those trees that were infected, was not so severe and easily observed, as in a hot summer. So that with fewer active cases than usual, and those often symptomatically slight, the disease did not attract much attention.

Decay

The number of queries about decay was very small, and with the exception of those on larch and conifers they all referred to single trees, and were therefore of comparatively little importance. The instance on conifers referred to an estate where *Fomes annosus* was causing considerable decay in thirty-year-old Japanese larch and Sitka spruce, growing as a second rotation on land which had carried a previous coniferous crop.

Soil Water Relations

In the period under consideration drought damage was hardly a possibility, and nearly all the enquiries placed under this head dealt with cases where excessive moisture in the soil damaged the root system. This occurred on a wide range of conifers, particularly following transplanting into the forest; presumably the damaged roots found it difficult to make fresh growth in cold water-logged soil. Douglas fir seems particularly susceptible to this kind of injury. In some cases the trees actually flushed, and then growth collapsed, because the inadequate root system could not support the new foliage. Although this trouble was in some cases connected with lifting-damage to the finer roots, some of the trees affected had been quite well lifted. One answer might possibly be to heel in the plants, intended for a wet cold area, in garden soil till root

growth had commenced, and then plant them late after the soil had become slightly drier and warmer. But this would have to be a matter for experiment. The damage was much more serious on Douglas fir and larch than on spruce, and it is probable that the latter could normally be used with greater safety, under these sorts of soil conditions.

Soil Nutrient Deficiencies

Several enquiries were made in which soil deficiency appeared to be a possible explanation of the damage. Inevitably lack of facilities for chemical analysis at the Research Station make any real investigation of such problems almost impossible.

Wind

Only two enquiries fall under this head. One was concerned with injury to the needles of Douglas fir in an exposed position, the other with actual breakage of young coppice shoots on chestnut stools.

General Enquiries

Two enquiries asked for all the available information on diseases of Norway spruce. Such a comprehensive query is, of course, virtually impossible to answer.

Unexplained Causes

Only thirteen queries are listed under this heading, and in some of these cases diagnosis was impossible, only because the material or information sent was inadequate, and the importance of the enquiry did not warrant a visit. On the other hand it must not be assumed that all the answers given to queries listed under other heads were absolutely definite. The words "probable", "possible", "we think", "we suspect" or "it seems likely" occur far too frequently in answers to enquiries. This is inevitable, when postal diagnosis is attempted, for only in very few cases is the material sent really adequate. There are still many instances of disease in trees, which defy explanation, even after exhaustive examination of the tree itself.

Taken as a whole the enquiries show a wide range of interest. They are divided between those where the sender has no real idea of the cause, and those where he has a fair idea, but requires confirmation, and possibly advice on treatment. The latter certainly form the minority. The second category of course includes a high proportion of the enquiries on such well-known diseases as Honey Fungus or Elm Disease. Many enquirers are satisfied by being given the name of the fungus concerned, even though this will not necessarily enable them to take practical steps against the disease. It is still unfortunate that comparatively few give full information about the conditions, under which the trees are growing, and the treatment to which they have been subjected in the past. Were this regularly done, the possibilities of "diagnosis at a distance" would be vastly increased.

The amount of work necessary for an enquiry varies greatly. The majority require a careful examination to see what fungi are present, as well as a more superficial examination to see what parts are alive, what evidences there are of injury and so on. In about twenty-five per cent, fungal attack seems a possible explanation, though no fungus fruit bodies can be found. In these cases bits of the diseased material are cultured, and the fungi growing out from them have to be identified, a skilled and exacting task.

FOREST ENTOMOLOGY

By Dr. MYLES CROOKE
Forest Entomologist

Sawfly Survey

During 1951, the status of various species of larch sawflies was investigated in the following Forest areas: Brecon (Brecknockshire), Crychan (Brecknockshire and Carmarthenshire), Radnor (Radnorshire), Mortimer (Herefordshire and Shropshire), Grizedale (Lancashire), Thirlmere (Cumberland), Thornthwaite (Cumberland), Greystoke (Cumberland), Slaley (Northumberland), Chopwell (Durham), Wark (Northumberland), Kielder (Northumberland), Harwood (Northumberland), Redesdale (Northumberland), Rothbury (Northumberland), Wauchope (Northumberland), Newcastleton (Roxburghshire), Kershope (Cumberland), Tinnisburn (Dumfries-shire and Roxburghshire).

The assessment of the population of the Large Larch Sawfly, *Pristiphora erichsoni* Htg. was, as in previous years, based on the total number of clutches of larvae which could be found in each locality. With the exception of Brecon, the figures for all areas indicated that the population of this species was on the increase when compared with the figures for 1950. In most areas the population increase was of considerable magnitude. For example in Kielder the increase was from 35 clutches in 1950, to 77 clutches in 1951, in Redesdale from 20 to 106, in Thirlmere from 123 to 237, in Mortimer from 43 to 110, and in Wark the largest increase recorded, from 7 to 275. In view of the destructive potentialities of this species, which has already caused major damage in Great Britain, the indications of a widespread increase in its occurrence are disturbing, and a close watch will continue to be kept on it in future seasons.

The status of various other sawflies associated with larch, which are at present of lesser importance, was also reviewed in 1951, over the same areas as were covered by the Large Larch Sawfly survey. The main species studied were *Pristiphora wesmaeli* Tisch., *P. laricis* Htg., and *Anoploynx duplex* Lep. As in previous years the population density was sampled by a standard technique of branch beating on known sample areas. The results indicated that the level of population of these species had in general remained low as in previous years, and had in many cases shown a slight recession when compared with the 1950 figures. Preliminary observations on the biology of a number of species of both larch and spruce sawflies were commenced at the Alice Holt laboratories during 1951.

Neomyzaphis abietina

The *Neomyzaphis* survey carried out in 1951, by circularising all Conservators of Forests, has resulted in the accumulation of some valuable data relating to the distribution of the pest under a variety of site and cultural conditions. In all, 57 completed census forms were returned. This knowledge will be used as a basis for the selection of sample plot areas in which, for a proposed period of five years, assessments will be made of the fluctuations in population from year to year in representative Sitka spruce plantations. Correlated with this, a detailed study of the effects of infestation on the rate of growth of the host trees will be made.

Intensive studies of population fluctuations carried out in Fermyn Wood, Northamptonshire, have confirmed that there are two main infestation peaks in the season, the first occurring in late May and early June, immediately prior to the mass production of alate (winged) females, and the second in October and November. The assessment of *Neomyzaphis* population in the sample plots referred to above will be synchronised with the first seasonal peak of infestation.

Parasites of Pine Shoot Moth

Large collections of Pine Shoot Moth (*Evetria buoliana* Schiff.) larvae were made during the season from Wareham Forest. From these many parasitic species have been reared which are being identified to provide information on the parasite complex associated with this Tortricid.

Sirex Parasites for New Zealand

During the year collections of *Ibalia leucospoides* Hochnw., a Cynipid parasite of *Sirex* spp., were made on behalf of the New Zealand authorities, and a consignment of 199 adults and 38 larvae was despatched to that country to be used there in an endeavour to effect biological control of *Sirex* spp.

MACHINERY RESEARCH

By R. G. SHAW
Machinery Research Officer

Since the formation of the Mechanical Development Committee in 1949 the number of prototype machines has increased to the point where some central store and workshop is required. A building will shortly be available at Bramshill Forest, Hampshire, where the nucleus of an experimental section has been formed. Bramshill is a convenient site as it is already the machinery centre of the South East (England) Conservancy and it is within easy reach of Headquarters. A start has been made on the provision of instruments to enable facts on mechanical performance to be established instead of having to rely on opinions.

Development during the past year includes:

British Tractors

A number of Fowler Marshall V.F. tractors have now come into normal forest use in various parts of the country, and the view is confirmed that they can take on a large proportion of the ploughing programme.

Tractors for use on very soft ground remain a problem, owing to the high cost of providing the special features that they require. The Cuthbertson Buffalo, which has a ground pressure of only $2\frac{1}{2}$ pounds per square inch, is on trial in Scotland, and appears able to operate on ground inaccessible to most other tractors.

Investigation is being made into the greater use of half-tracked tractors to reduce ploughing costs. A Fordson Major half-track machine has been modified to increase the performance under the severe ground conditions often met in

forestry operations. These modifications consist of a rearrangement of the front axle and steering to permit the use of extra large wheels, 58 inches in diameter and requiring a tyre of size 11″ x 36″. Preliminary trials have given encouraging results.

Ploughing

There has been no commercial development of mounted ploughs on full-tracked tractors in the larger sizes, owing to the inherent steering problems that are involved. An investigation in this direction has been carried out by the commission in Scotland during the past year with some success. A prototype mounted plough has been in use for several months on an International T.D.9 tractor, and a further six have been ordered for a larger field trial. The advantages of the mounted plough over a trailed plough for forestry use are improved manoeuvrability on the headlands, simplified road transport, and the elimination of the plough carriage, which requires much mechanical maintenance. The possibility of fitting mounted ploughs to Fordson Roadless half-track tractors is being explored.

Cableways

The power-operated cableway has now been used successfully on several sites providing very different conditions. Three sets of this equipment with a range of 600 yards each, have now been made.

Clearance of Derelict Woodland

A grubber blade on an International T.D.14 tractor has been found to be very effective in clearing rhododendron. It is also effective on other types of growth, but with this method there remains the problem of disposing of the waste. Burning in windrows adds to the labour costs, and means a delay to allow the windrows to dry out. There is still no reliable information as to the total cost of the operation, or the suitability of the ground for planting after clearance.

The Giant Rotavator is being tested on the exceptionally heavy work involved in the clearance of old woodland. Several modifications have been made and more are in hand by the makers. A view of this machine on trial in coppice regrowth at Alton Forest, Hants. is shown in Plate XI.

Both these machines are now on trial to establish the cost of clearance per acre. Sample plots which have been cleared by both methods, followed by different cultivation operations, have been prepared to provide comparative data.

Road Haulage

Attention has been given to new techniques in vehicle repair. In this connection a number of vehicles are running with chromium-plated cylinder liners with success. Easily portable high-pressure lubricators have been provided at many of the isolated garages to improve the standard of maintenance.

Haulage over Soft Ground

Experiments have been carried out with a multi-wheeled trailer and with a four-wheel trailer using large-diameter low-pressure tyres. In the case of the multi-wheeled trailer the performance has not justified the high cost. The large-diameter wheels offer far greater scope both in four-wheel and two-wheel form. Attention is being given to light rubber tracks which are being developed commercially for load-carrying trailers.

Fire Protection

A light portable pump which can deliver ten gallons of water per minute against a ninety foot head is now in wide use by the Commission. The weight of this unit is 77½ pounds. Development is taking place to increase the maximum head, which is at present 124 feet. One of the pumps has been mounted in a Land Rover, the pump being driven from the power take-off on the gear box. Trials will take place during the summer of 1952.

Mechanisation of Nursery Operations

A test rig has been made to experiment with the mechanical application of formalin solutions to seed beds. Initial tests have been successful. A low-volume spraying machine has been successfully developed for the application of weed-killers. This is basically a commercial machine adapted to fit the standard forest nursery seed beds. Experiments with machines for root pruning of seedlings in the beds have continued, and the best results up-to-date have been obtained in Scotland with a knife carried below the runners of a sledge. The sledge is mounted on the hydraulic linkage of a Ferguson tractor.

UTILISATION DEVELOPMENT

By E. G. RICHARDS
Utilisation Development Officer

The advisory Committee on the Utilisation of Home Grown Timber recommended that the lines of investigation which might most profitably be pursued by the Utilisation Section were those concerned with the problems of marketing small-sized thinnings, scrub and coppice; whilst the possibilities of finding markets for sawmill and other waste should not be overlooked.

Small Conifer Thinnings

An inquiry into the problems of marketing small sized conifer thinnings in the South of England established that the then current demand for this type of produce exceeded available supplies. The degree to which individual private estates were able to take advantage of this situation depended for the most part on the amount of enterprise and knowledge shown by each estate in organising the marketing of its produce. Whereas, on the one hand, certain estates were able to sell all their thinnings at comparatively high prices, on the other hand a number of estates were selling only a part of their thinnings—often at somewhat poor prices. Thus the problem of advising owners as to how to sell their small sized conifer thinnings to the best advantage remains important, even when there is a large demand for this class of material.

Small Hardwood Thinnings

The status of the charcoal manufacturing industry in Great Britain was fully investigated, with particular reference to that industry's present and future requirements of timber. Although hardwood thinnings of almost any shape and size are acceptable, manufacturers have been unable to obtain their full requirements of timber. This is to a considerable extent due to the fact that prices

for charcoal wood are often lower than those pertaining in other markets, such as, for example, the firewood market. Nevertheless, where woodlands are situated reasonably near to charcoal manufacturing plants, there is a possibility of owners being able to fix long-term contracts for considerable quantities of hardwood thinnings. Selected material from scrub areas might also well be saleable in this market.

Scrub and Coppice

Information on the location of the coppice and coppice-with-standards areas is already known from the 1947 Census of Woodlands data, in considerable detail. Nothing is known at present, as to the area of coppice being worked by the underwood industry. Accordingly the Rural Industries Bureau have kindly undertaken to conduct a survey to estimate the acreages of coppice, by species, which are currently being worked. The results of this survey, considered in relation to the Census of Woodlands data, will also give an indication of the area of coppice for which no conventional markets exist. Before considering to what extent it might be possible to find new markets for coppice not at present required and not likely to be required in the future by the underwood industry, it was thought desirable to obtain information on the production of different species of coppice on various sites.

Hazel was the species selected for the first series of measurements, and during the year under review over fifty one-tenth acre plots of hazel coppice in six different localities were felled and measured by the Mensuration Section. As well as providing data on the production of hazel coppice, this experiment will also serve as a guide as to the validity of the somewhat unorthodox method of volume measurement of coppice which was resorted to. Briefly the method consisted in obtaining for each one-tenth acre plot, by direct weighing, the weight of fresh-felled hazel coppice. Samples of this fresh-felled material were weighed, and were then dried at 105°C. and re-weighed. From all these data the oven-dry weight of hazel coppice per acre was determined. The specific gravity of the oven-dry samples was then obtained, and these figures applied to the oven-dry weight per acre to give volume of hazel coppice per acre in cubic feet; an adjustment was made to allow for the shrinkage that occurs in drying

LIBRARY AND DOCUMENTATION

By G. D. KITCHINGMAN
Documentation Officer

Library. The number of books in the library on the 31st March, 1952 was 1,785, an increase of 685 during the last three years. Loans of books increased from 526 to 1,043. Thirty-seven volumes of periodicals were bound, bringing the total to 918.

Information files. This section of the library increases slowly, but there is still much loose material awaiting documentation and filing.

Documentation. Documentation is very much behindhand, and the accumulation of arrears causes serious concern. In spite of this, the number of index cards has increased during the year from 26,000 to 40,000, representing about 12,000 references, and lists of references on literature were supplied as required to many of the research staff.

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

1. Alphabetical Index to the Geographical classification of the State Forests of Great Britain.
2. Literature of Beech.
3. Regional Background of British Forestry.
4. A basic list of books for Conservancy Libraries.

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

PHOTOGRAPHY

By A. I. ANDERSON
Senior Photographer

Two conservancies were visited—North Wales and East Scotland, for the purpose of taking photographs for record. The tour of North Wales was completed, but owing to the lateness of the season and work on the Culbin film much of the work in East Scotland had perforce to be held over.

During the period under review the film entitled "Culbin Story" was completed.

PUBLICATIONS

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

HOLMES, G. D. and MATTHEWS, J. D. — *Girdling or Banding as a means of increasing Cone Production.* Forest Record No. 12 (1951).

HOLMES, G. D. and IVENS, G. W. — *Chemical Control of Weeds in Forest Nursery Seedbeds.* Forest Record No. 13. (1952)

HOLMES, G. D. — Methods of Testing the germination quality of Forest Tree Seeds and the interpretation of the results. Leader in *Forestry Abstracts.* Vol. 13. No. 1. pp. 5-15. (1951).

BROWN, J. M. B. — Notes on Chiltern Beechwoods. *Quarterly Journal of Forestry.* Vol. XLVI. No. 1. pp. 5-15. (Jan. 1952)

MACDONALD, J. Climatic Limitations in British Forestry.
Quarterly Journal of Forestry, Vol. XLV. No. 3. (July 1951)

British Woodlands and Their Production.
Proceedings of the Technical Section of The British Paper and Board Makers' Association. Vol. 33. Pt. 2, p.337. (1952)

FAULKNER, R. Shelterbelts in Nebraska, U.S.A.
Scottish Agriculture. Vol. XXXI. No. 3. pp. 147-150. (1952)

HUMMEL, F. C. An Experiment on the Sampling of early Thinnings.
Forestry. Vol. XXV. No. 1. pp. 19-31. (1952)

HUMMEL, F. C., IRVINE, T. W. and JEFFERS, J. N. R. *General Volume Tables for Corsican pine in Great Britain.*
Forest Record, No. 14. (1951)

HUMMEL, F. C., IRVINE, T. W. and JEFFERS, J. N. R. *General Volume Tables for Japanese larch in Great Britain.*
Forest Record No. 14. (1951)

HUMMEL, F. C., IRVINE, T. W. and JEFFERS, J. N. R. *General Volume Tables for Douglas fir in Great Britain.*
Forest Record. No. 15. (1951)

JEFFERS, J. N. R. Use of Range/Standard Deviation Tables.
Forestry. Vol. XXV. No. 1. pp. 66-68. (1952)

RICHARDS. E. G. The Marketing of Small Sized Conifers.
Journal of the Land Agents Society. Vol. LI. No. 2. (Feb. 1952). pp. 61-63.

PEACE. T. R. Poplar as a Farm Crop.
Agriculture Vol. 57. No. 10 (Jan. 1952). pp. 473-477.

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

SUB-COMMITTEE ON NUTRITION PROBLEMS IN FOREST NURSERIES.

SUMMARY REPORT ON 1951 EXPERIMENTS

By DR. E. M. CROWTHER and BLANCHE BENZIAN
Rothamsted Experimental Station, Harpenden, Herts.

Introduction

When the Sub-Committee on Nutrition Problems in Forest Nurseries began its work in the autumn of 1944, it was known that many of the older forest nurseries were incapable of producing usable one-year seedlings and one-plus-one transplants of Sitka spruce and other sensitive conifers. Such plants had, however, been grown successfully in clearings in heathlands or conifer forests with the aid of liberal dressings of compost. At that time it was often assumed that composts acted mainly by stimulating fungi forming mycorrhizal associations with the roots, and the supply of nutrients to plants played a relatively insignificant role. There was, however, little experience or experimental evidence on the use of fertilizers in seedbeds, apart from occasional tests on some less soluble materials, such as bone meal and basic slag, and thus there had been no opportunity to test, in the forest, plants of roughly equal size raised with composts and fertilizers.

The early investigations carried out for the Sub-Committee by the Rothamsted staff and the Research Branch were devoted to developing suitable techniques for small plot experiments in seedbeds, transplant lines and forest plantings, and to comparing the effects of composts and fertilizers, separately and together. These preliminary experiments showed that the effects of various kinds of composts were related to the amounts of the major plant nutrients present, and that there were no outstanding or consistent differences in size or forest performance between plants raised with composts or fertilizers, respectively. Plants from some of the early experiments are still under regular observation in "forest extension" experiments.

The early experiments also showed that growth of Sitka spruce and Scots pine seedlings could be improved in old established nurseries by steaming the soil or by treating it with formalin or acidifying agents.

In recent years much of the work has been devoted to series of parallel experiments in some or all of six nurseries in the South of England. Four of these are Research Nurseries (two at Kennington, Bagley Wood and

Wareham) and two Conservancy Nurseries in which sections have been specially reserved for these investigations (Ringwood and Ampthill). Three of the nurseries had been in use for some twenty years and three were new nurseries. Most of the experiments have been on plots of one square yard, separated by twelve or eighteen inch "buffers" across the beds, and by two-feet alleys between beds. In many experiments three or four successive crops of one-year Sitka spruce are taken to obtain results under different weather conditions, with some indication of residual or cumulative effects. To prevent the introduction of extraneous soil, the beds are not "made up" after their original preparation, and plots, buffers and alleys are dug separately. This technique is unsuited for measuring long-term effects on soil fertility. Two series of experiments were commenced in 1951, in new extensions to the Kennington and Wareham nurseries, using larger plots with suitable surrounds from which the plots could be "made-up", and with strips of undug soil to prevent any mechanical transfer of soil between plots. (In the new extension at Kennington Nursery it was necessary to design and install grassed banks and water-ways to protect a sloping site against erosion. Some heavy storms showed both the need for and the success of the installations). The new long-term experiments are planned to test various three-year rotations, including Sitka spruce seedlings and transplants, green crops and fallow, on plots receiving either compost or fertilizers every year. The seedlings will be tested as transplants in extension experiments, with either compost or fertilizers, and both seedlings and transplants will be tested in forest plantings.

A number of single-year experiments are also conducted each season. As some of these may leave appreciable residues in the soil, the sites cannot be used again for some years, and there is difficulty in finding suitable new sites in the congested Research Nurseries. To economise space, a number of experiments have been made with plots 15 or 18 inches wide, across continuously sown beds one yard wide, where the treatments can be applied after the last digging in preparing the beds.

In four experiments in three nurseries, broadcast sowings were replaced by six rows of different species to obtain some indication of the extent to which other conifers resemble Sitka spruce, the main indicator species.

Each year a number of extension experiments are made in transplant lines or forests to test the performance of plants raised with experimental treatments. These experiments are particularly laborious, and must be repeated in several seasons and under contrasted conditions before any reliable conclusions can be drawn. They are needed because there appear to be no sound criteria, apart from size, for assessing the potential value of seedlings and transplants. Two mutually contradictory opinions were frequently given in the early meetings of the Sub-Committee. One view was that survival and growth could be assessed only by very detailed mycological examination of the root system. The other was that well-furnished plants of reasonable size will grow equally well, whatever their nursery treatment may have been.

Plant Nutrients

After the first few years of this work a compost of bracken and hop waste was adopted as standard, and the methods of making it were carefully controlled. The merits and economic value of composts cannot be properly assessed until it is known whether their main functions are to supply major nutrients, to affect the physical properties of the soil, to change its biological conditions, or to act in some other way. An essential step in analysing all the manifold and hypothetical possibilities is to discover how inorganic sources of plant nutrients

can be used efficiently, and then to compare compost with fertilizers, preferably over long periods on a variety of soils. Comparing equal amounts of nutrient elements in composts and fertilizers would be of little theoretical or practical value, for it would be dangerous to add as much nitrogen in fertilizer salts as can be given safely in the inert forms present in composts. At the rates used in 1950 experiments, the compost dressings contained from four to six times as much nitrogen, twice as much phosphorus and three to six times as much potassium as were tested in the standard dressings of fertilizers. There are still considerable difficulties in finding appropriate fertilizer treatments for forest nursery soils, since there is little past experience to draw on, either in this country or abroad. Many of the nursery soils are very light and very acid. They have low reserves of nutrients and little "buffer capacity" against changes; they are liable to serious losses by leaching. Germinating seeds are known to be sensitive to salts, and there is always a risk of dry spells in spring or of a prolonged summer drought.

Many of the early experiments were devoted to testing alternative forms and rates of nitrogen, phosphorus and potassium fertilizers and to different times of applying nitrogen fertilizers. In several years it was noticed that on the very light and acid soils, large plants grown with moderate dressings of fertilizers developed abnormal symptoms ("Hard yellows") in the upper needles towards the end of the season. Chemical analyses showed that such plants had low contents of magnesium. Experiments in 1951, at three nurseries, showed that these symptoms could be eliminated by supplying magnesium either as sulphate or as dolomitic limestone. As an indication of the sensitivity of one of the lightest soils in this series (Ringwood nursery), it may be mentioned that in 1951 magnesian limestone controlled the yellow symptoms, but magnesian limestone and high-calcium limestone in modest dressings reduced the heights of seedlings.

Plant analyses have shown that seedlings from compost-treated plots often contain more potassium than those from fertilizer plots. As had already been pointed out the composts normally supply much more potassium than has recently been given in the fertilizer dressings. In 1952, a new series of experiments has been started in several nurseries to test the effects of increasing the amount of potassium fertilizer, and of including magnesium sulphate in the fertilizer dressings. Alternative methods of incorporating superphosphate into acutely deficient soils are also being studied.

Although much still remains to be done in developing the principles and improving the technique of using fertilizers in forest nurseries, general recommendations on manuring based on our results have been incorporated in Research Branch Circulars and Silvicultural Circulars since the winter of 1946/47. The methods have been widely used in Conservancy Nurseries in England and Wales.

The 1951 Season

The early spring was very wet and sowing was inevitably late. There was a dry spell in June and a wet autumn. Plants grew well, but in comparable experiments were not quite as large as in 1950. In both of these years there was little discoloration due to phosphorus deficiency, but shortage of phosphorus was still the principal factor limiting growth in nurseries known to be deficient in this nutrient. There were marked potassium deficiency symptoms and large reponses to potassium in several nurseries in both years. Formalin treatment gave particularly large plants in 1951, some of the experiments having many plots which experienced observers regarded as approaching perfection.

Such successes in a difficult season were a tribute to the skill of the foresters in charge.

Fertilizers

Many experiments since 1946 have shown that acidifying agents, such as sulphuric acid, sulphur, aluminium sulphate and ammonium sulphate may improve the growth of Sitka spruce in established nurseries with neutral or slightly acid soils. There may, however, be disturbances in dry seasons from surplus salts formed by the acidifying agents, or from the oxidation products of sulphur. Attempts have been made to exploit the acidifying effect of top-dressed ammonium sulphate. In an experiment (K.31) at Old Kennington nursery, sown with Sitka spruce each year since 1949, dressings of ammonium sulphate have been applied on four occasions—before sowing, in June, July and August—and compared with equivalent amounts of "Nitro-Chalk" (a mixture of ammonium nitrate and calcium carbonate which has only small effects on soil reaction). It was considered possible that each top dressing of ammonium sulphate might produce a little local acidification of the surface soil, and in consequence, maintain for a time an appreciable concentration of ammonium, whilst that in "Nitro-Chalk" would be quickly converted to nitrate.

SOIL ACIDIFICATION BY TOP-DRESSINGS OF AMMONIUM SULPHATE

Old Kennington experiment (K.31) repeated for three seasons with one-year Sitka spruce seedlings.

Table 34

Total dressing per sq. yd. per annum	Height in inches			pH 1951
	1949	1950	1951	
No Nitrogen	0.8	0.7	0.6	7.0
"Nitro-Chalk"				
6 grams Nitrogen	0.9	0.9	0.8	7.0
12 grams Nitrogen	0.8	1.1	0.9	7.1
18 grams Nitrogen	0.8	1.1	0.9	7.0
Ammonium Sulphate				
6 grams Nitrogen	0.9	1.3	1.2	6.6
12 grams Nitrogen	0.8	1.8	1.5	6.5
18 grams Nitrogen	0.9	1.8	1.6	6.0
Standard error	0.04	0.11	0.06	—

Dividing the ammonium sulphate over the season would reduce the risk of harmful excess of salts. Ammonium sulphate was applied at rates of roughly 3, 6 and 9 cwt. per acre per annum. In the drought of 1949 Sitka spruce grew very badly, but there was no damage from the nitrogen fertilizers. In 1950 and 1951 the ammonium sulphate plots had conspicuously better Sitka spruce than the "Nitro-Chalk" plots. It was easy at the end of both seasons to pick out all plots which had received ammonium sulphate. Mean heights of 1.5 inches or over are good for this part of the Old Kennington nursery.

In 1951, a new series of experiments was carried out on eighteen-inch plots of continuously sown beds at six nurseries to compare equivalent applications of ammonium sulphate and "Nitro-Chalk" on one, two or three occasions throughout the season. Ammonium sulphate gave significantly taller plants at the three old nurseries (Old Kennington, Ampthill and Ringwood) but not at the three new ones (Kennington Extension, Bagley Wood and Wareham).

By the end of the season the pH values were about 0.3 lower on the ammonium sulphate plots. In these experiments nitrogen fertilizers gave significant increases at only one nursery when applied before sowing, at four when applied in June, and at five when applied in August. The two summer top dressings had little advantage in 1951 over the single application in August, but dividing the dressings reduces the risk of missing a critical period. Attempts were also made in these experiments to assess the value of potassium sulphate raked into the soil before sowing or applied as a summer top dressing. The application before sowing slightly reduced heights at Old Kennington and Ampthill nurseries, and slightly increased heights at the other nurseries. The summer top dressing had somewhat smaller effects at most nurseries and was ineffective at Wareham, where potassium sulphate raked-in before sowing markedly increased heights.

In a third-year experiment at Wareham on nitrogen, phosphorus and potassium fertilizers applied annually, each square yard plot carried rows of six kinds of conifers. The results in Table 35 show that the six species behaved in much the same way, giving highly significant responses to each of the three fertilizers. This suggests that results for Sitka spruce may be applied with some confidence to other conifers. In this experiment there was also clear evidence of a residual benefit from superphosphate applied in a mixed fertilizer in 1949, but there was no evidence of any residual benefit from the potassium in the mixed fertilizer. It is often asserted that superphosphate is unsuitable for very acid soils and has low residual effects. In our experiments in nurseries and forests superphosphate has proved equal to or better than alternative forms. In forestry, as in agriculture, there is much to be said for learning how to use standard fertilizer materials instead of relying on by-products and composts of uncertain composition and properties.

EFFECT OF FERTILIZERS ON SIX SPECIES OF CONIFERS

Table 35 — Third-year experiment at Wareham (W.46) on one-year seedlings, sown 1951

	Sitka spruce	Tsuga	Corsican pine	Pinus contorta	Jap. larch	Douglas fir
Mean height in inches	0.8	0.6	1.2	1.6	3.0	2.3
Effect of fertilizers on height *as percentage of mean*						
Nitrogen	59	23	23	37	32	26
Phosphorus	76	39	35	74	66	45
Potassium	41	32	33	42	41	43
Standard error	14	10	4	11	10	8

Compost, Fertilizers and Formalin

In 1950 a parallel series of experiments was started at five nurseries with factorial tests on compost, fertilizers and formalin. The treatments were repeated on the same plots in 1951, with results set out in Table 36 for four of the eight treatments. (The extreme treatments without manure and with both fertilizers and compost are omitted).

The data in the first part of Table 36 show that in nine of the ten comparisons the compost plots had lower plant numbers than the fertilizer plots. This kind

of result has been obtained in several other experiments and seasons. There is no reliable evidence to explain the loss of plants through compost treatment. Losses through using compost are still more striking in numbers of usable seedlings. (This difference does not show on formalin-treated plots at the two very acid nurseries, where almost all of the plants were usable.)

COMPOST, FERTILIZERS AND FORMALIN AT FIVE NURSERIES

Table 36 Second-year experiment on one-year Sitka spruce seedlings, 1951

	Old Kennington K 42	Ringwood R 32	Kennington Extension KE 49	Bagley B 26	Wareham W 55
		Total plants per square yard			
No formalin					
Compost....	400	410	900	1,000	1,080
Fertilizer....	550	770	1,130	1,480	1,040
With formalin					
Compost....	680	380	890	1,200	960
Fertilizer....	790	710	1,190	1,480	1,110
		Plants over 1.5 inches, per square yard			
No formalin					
Compost....	0	50	760	520	590
Fertilizer....	10	190	1,060	890	960
With formalin					
Compost....	170	320	790	1,090	940
Fertilizer....	400	610	1,140	1,190	1,080
		Mean height in inches			
No formalin					
Compost....	0.6	1.1	2.6	1.7	1.8
Fertilizer....	0.8	1.2	3.0	2.0	2.8
With formalin					
Compost....	1.3	2.5	3.3	3.1	3.6
Fertilizer....	1.7	2.4	3.8	2.7	3.4

Formalin appreciably increased plant numbers at only one of the five centres. The general benefit from using formalin cannot, therefore, be ascribed to reducing deaths through "damping-off". It is, of course, possible that related fungi may damage roots and restrict growth late in the season. There have been a few cases in other experiments in old-established nurseries and in our pot experiments in which formalin has increased plant numbers when there were high losses from "damping-off".

It is noteworthy that formalin increased mean heights in the 1951 experiments even in the very acid nurseries where good seedlings could be grown without formalin treatment.

Steam, Formalin and Fertilizers

In March, 1949, an experiment was laid out at Ampthill nursery with four large steamed plots and four unsteamed plots. Each of the eight plots was then divided into six plots for tests on no further treatment, formalin and acid, each with and without nitrogen fertilizer. One-year Sitka spruce seedlings were

grown for three successive years, only the nitrogen treatment being repeated. Soil samples were taken periodically for chemical and microbiological analyses by Mr. R. G. Warren and Miss L. M. Crump. One general result was that the plots treated with formalin, steam or acid had more ammonia than the untreated plots, even after the samples had been incubated for a fortnight in the laboratory. It is possible that the maintenance of a high ammonia content by checking nitrification may favour the growth of young conifers.

EFFECT OF STEAM, FORMALIN AND ACID

Three-year experiment on one-year Sitka spruce seedlings, Ampthill Nursery. (Am. 1)

Table 37 — All treatments applied in 1949 only

	Mean height in inches					
	1949		1950		1951	
	No Steam	Steam	No Steam	Steam	No Steam	Steam
No formalin, no acid	1.06	2.47	1.33	1.69	0.86	0.65
Formalin	2.07	2.58	1.83	1.97	0.82	0.76
Acid	failed	failed	2.02	2.79	0.99	1.14
Standard error	0.07	0.09	0.08	0.12	0.05	0.04

The mean heights of one-year Sitka spruce seedlings are given in Table 37, averaging plots with and without nitrogen fertilizer, which had only small effects. In 1949, acid applied a few weeks before sowing killed the seedlings, but the acid-treated plots gave the best seedlings in 1950 and 1951. Steam and formalin gave great improvements in 1949, some residual benefit in the second year and none in the third year. The advantage of steam over formalin would be too slight to justify the extra cost and the serious complications and risk of delay in nursery work, such as occurred in the 1950 experiments in this nursery. No further experiments on steaming were undertaken after 1950.

Fertilizers and Formalin

A number of experiments have been laid out to obtain more information about the effects of formalin and the technique for using it to best advantage.

In parallel experiments at three nurseries, summarised in Table 38, formalin treatment in 1951 was tested factorially with residues from formalin in 1950, and with nitrogen, phosphorus and potassium fertilizers applied in both seasons. Formalin in 1951 greatly increased heights at all three nurseries, but plots which had received formalin in both years gave smaller plants than those with formalin in 1951 only. Where no formalin was given in 1951, there were appreciable residual effects from formalin in 1950. It is known that formalin profoundly affects the microflora of the soil and that some oranisms can decompose formalin or products derived from it. It is possible that the microflora developed by applying formalin may accelerate the decomposition of subsequent additions. In these experiments formalin treatment greatly increased the response to superphosphate. The excellent plants grown with formalin at Kennington Extension showed no further response to potassium fertilizer, but plants without formalin in 1951 showed a good response to potassium (from 1.9 to 2.6 inches).

EFFECT OF FERTILIZERS, FORMALIN AND FORMALIN-RESIDUES

Second-year experiment on one-year Sitka spruce seedlings, 1951

Table 38 P = Phosphorus

1950 *treatment*	1951 *treatment*	Old Kennington K 44	Ringwood R 33	Kennington Extension KE 50
Approximate pH:		6.4	5.8	5.2
		Height in inches, 1951		
—	—	0.5	0.6	2.0
Formalin	—	0.8	0.9	2.5
—	Formalin	1.4	1.5	3.4
Formalin	Formalin	1.2	1.3	3.2
no P	—	0.5	0.7	2.1
P	P	0.8	0.8	2.4
no P	Formalin	1.0	1.1	3.0
P	P + formalin	1.6	1.8	3.6
Standard error		±0.05	±0.07	±0.11

Experiments were made at six nurseries to test mid-winter against late-winter applications of formalin at three rates. Formalin gave large improvements in all nurseries except the very acid one at Bagley Wood. The plants grown with formalin at all nurseries were larger than those grown without formalin at the two very acid nurseries. The plants in the Old Kennington experiment were unusually good for this nursery. Here and in several other nurseries we have found fairly sharp breaks between good and bad sites, which seem to reflect differences in past cropping and management. It is difficult in such cases to assess the relative importance of nutritional and disease factors, but there are indications that the poor sites have either received unsuitable materials (e.g. limestone) or become heavily infected with pests or pathogens. There is little sign that they have been exhausted of nutrients. "Wrongly managed" may be a better term than "worn out" to describe such conditions.

EFFECT OF FORMALIN APPLIED IN WINTER AND SPRING

Table 39 First-year experiment on one-year Sitka spruce seedlings, 1951

	Old Kennington K 48	Ampthill Am 18	Ringwood R 39	Kennington Extension KE 58	Bagley Wood B 31	Wareham W 59
Initial pH:	6.8	6.2	5.0	5.4	4.1	4.6
			Height in inches			
No formalin	1.6	1.3	1.6	2.3	2.2	2.1
Formalin applied:—						
Dec./Jan.	3.4	2.4	2.5	2.8	2.4	3.0
March	3.6	2.7	2.4	3.3	2.4	2.9
Standard error	0.09	0.08	0.05	0.10	0.10	0.15

Winter applications of formalin were only slightly inferior to those given three weeks before sowing. The earlier applications might be more convenient and safer in practice. On the average of all nurseries and both times of

application, the mean heights for 0, 125, 250, 500 ml. formalin (suitably diluted) per square yard were 1.9, 2.6, 2.8, 3.0 inches respectively. In practice about 250 ml. formalin per square yard would be ample and even smaller dressings might be tried.

At three old nurseries experiments were conducted on the eight treatments providing factorial tests on a heavy dressing of ammonium sulphate in winter to acidify the soil, March application of formalin, and two summer top-dressings of ammonium sulphate. In the Old Kennington experiment six species were sown in rows in each square-yard plot; in the two other nurseries Sitka spruce was broadcast. All centres and species showed large responses to formalin, Sitka spruce being the most responsive. Five species at Old Kennington, and Sitka spruce at Ampthill, showed significant responses to winter treatments with ammonium sulphate. All species except Corsican pine showed significant responses to summer top dressings of ammonium sulphate. Although the joint effects of two treatments were generally somewhat less than the sum of the separate effects, the effects of combined treatments (which are indicated roughly by adding the percentage effects given in Table 40) led to vivid contrasts.

FIRST YEAR EXPERIMENT ON ONE-YEAR SITKA SPRUCE SEEDLINGS AT THREE NURSERIES AND ON FIVE OTHER SPECIES AT OLD KENNINGTON NURSERY; 1951

Table 40

	Old Kennington K 49 pH 6.4						*Ampthill* Am 20 pH 7.2	*Ringwood* R 40 pH 5.8
	Sitka Spruce	Tsuga	Corsican Pine	Pinus Contorta	Jap. Larch	Douglas Fir	Sitka Spruce	Sitka Spruce
Mean height, inches	2.6	1.6	1.5	2.7	7.1	4.1	1.8	1.6
	Height increase from treatment as percentage of mean							
Winter amm. sulphate	23	31	12	2	20	9	9	(—11)
Formalin....	59	26	28	52	31	33	77	58
Summer amm. sulphate	11	40	5	19	15	16	17	19
Standard error	2.5	4.6	3.3	2.2	3.0	2.8	4.1	6.7

During each of the last few seasons a number of possible alternatives to formalin have been examined in the hope of obtaining clearer indications on the mechanism of "soil disinfection" or "partial sterilization", and of finding materials more convenient to apply in the nurseries. Paraformaldehyde, a solid polymer of formaldehyde, has given good results in a few experiments but it has sometimes failed. Closer study of the conditions will be needed before it can be used safely in forest nurseries. In experiments over six seasons, we have rarely failed to obtain responses to formalin in the neutral or slightly acid nurseries discussed in this Report, and, in some seasons, we have even had good results in very acid nurseries on heathland or forest sites. Our irregular results with paraformaldehyde raise the question whether some failures with formalin in Conservancy "user-trials" may have been due to using a polymerised formalin or one stabilised by some harmful ingredient. In the last few years we have been careful to select formalin solutions which do not readily polymerise.

In tobacco seedbeds in the United States good results have been obtained with urea or mixtures of urea and calcium cyanamide, applied in very heavy dressings many weeks before sowing. We did not wish to add large amounts of basic calcium and therefore tried urea alone and together with a polymer of cyanamide. The results with these treatments and with hexamine and gammexane were not

promising. It is a strange circumstance that formalin treatment for conifer and tobacco seedbeds was abandoned years ago in the United States, whereas none of the alternatives we have tried have approached formalin in efficiency and reliability. Chlorpicrin and ethylene dibromide are being tested in 1952.

Treatment of Transplant Beds

In an experiment at Old Kennington there were marked responses in the colour and early growth of transplants from heavy dressings of ammonium sulphate applied in mid-winter, but no benefit was shown in the final heights. Formalin applied in winter markedly increased heights. The gain from formalin was less on plots which had received the heavy ammonium sulphate treatment on the same day. This might be ascribed to a chemical reaction between the ammonium and the formalin. In repeating the treatments in 1952, an interval of a month was allowed between the ammonium sulphate and the formalin treatments, but this left only a month between formalin-treatment and lining-out, and many plants were killed on the formalin plots.

Forest Extension Experiments

The early extension experiments were inevitably scrappy. They were intended mainly to test whether plants raised with unusual treatments would grow well in the forests. Comparisons between experiments may include effects from site differences in nurseries and forests. Only recently has it become possible to compare, within a single forest experiment, plants differing in age, treatment and nursery of origin. Some of the results from 1948 plantings retain a certain interest provided their limitations are recognized. Table 41 shows the average results in three forests in extension experiments from four nurseries, two with one-plus-one transplants and two with one-year seedlings of Sitka spruce and Scots pine. The nursery experiments had tested either composts in conjunction with fertilizers or fertilizers alone. In three of the series there are only trivial differences according to whether or not the plants had been grown with compost in the nurseries. The Wareham one-plus-one transplants from the fertilizer experiment were inferior to those from the compost experiment, but it happened that the fertilizer-transplants of 1947 (reported in Tables 41 and 42) had been grown without liming on a piece of very acid and irregular heathland (pH below 4.0) and probably suffered from deficiencies of calcium and magnesium aggravated in a drought year by heavy fertilizer dressings.

FOREST PERFORMANCE OF SEEDLINGS AND TRANSPLANTS FROM NURSERY EXPERIMENTS ON COMPOSTS AND FERTILIZERS

Mean height in inches, 1951, after four years in three forests:
Sitka spruce—Broxa (Allerston Forest), Dartmoor, St. Gwynno
Scots pine —Broxa (Allerston Forest), Dartmoor, King's Forest.

Table 41

	Sitka spruce raised with		*Scots pine* raised with	
	Compost + Fertilizers	Fertilizers only	Compost + Fertilizers	Fertilizers only
Nursery				
1+1 ex Wareham	34	29	26	24
1+1 ex Kennington Extension	37	37	30	31
1+0 ex Wareham	28	28	22	20
1+0 ex Wytham	24	23	22	23

A more elaborate experiment with a different basis of comparison was laid out in 1948. Batches of seedlings and transplants were taken from the Old Nursery at Wareham, where they had been grown with compost on repeatedly composted soil, and also from the New Nursery, where they had been grown with fertilizers as the first crops after clearing the heath. The four lots were planted in the forests in 4 × 4 Latin Squares, half of each plot receiving NP fertilizers. The results in Table 42 show that seedlings grew well, except at King's Forest, and on unmanured land at Decoy Heath, where both seedlings and transplants Sitka spruce soon went into check. At Broxa the Sitka spruce seedlings reached about the same height as the transplants. NP fertilizers had marked effects on Sitka spruce, except at St. Gwynno, and on Scots pine at Broxa and Decoy Heath.

HEIGHTS AFTER FOUR SEASONS IN FORESTS OF WAREHAM SEEDLINGS AND TRANSPLANTS RAISED WITH COMPOST IN THE OLD NURSERY AND WITH FERTILIZERS IN THE NEW NURSERY

Table 42

	Height in inches, 1951				
	At planting 1948	After 4 years in forests, 1951			
		Broxa (Allerston)	Dartmoor	Decoy (Wareham)	St. Gwynno
SITKA SPRUCE					
Unmanured in forest					
1+1 ex Old nursery	7.2	35	19	14	45
1+1 ex New ,, ...	5.9	28	18	11	44
1+0 ex Old ,, ...	2.4	32	13	6	34
1+0 ex New ,, ...	1.8	34	16	7	38
NP fertilizer in forest					
1+1 ex Old nursery	7.2	47	32	27	46
1+1 ex New ,, ...	5.9	44	33	22	44
1+0 ex Old ,, ...	2.4	38	22	20	35
1+0 ex New ,, ...	1.8	42	28	29	38
SCOTS PINE					King's Forest
Unmanured in forest					
1+1 ex Old nursery	2.8	28	28	22	27
1+1 ex New ,, ...	4.1	30	27	22	27
1+0 ex Old ,, ...	2.2	22	19	13	18
1+0 ex New ,, ...	2.3	30	21	14	18
NP fertilizer in forest					
1+1 ex Old nursery	2.8	35	28	37	25
1+1 ex New ,, ...	4.1	39	30	37	28
1+0 ex Old ,, ...	2.2	29	22	31	17
1+0 ex New ,, ...	2.3	33	24	32	17

The Sitka spruce seedlings from the New Nursery grew taller than those from the Old Nursery, but the transplants from the New Nursery remained smaller than those from the Old Nursery. Scots pines from the Old and New Nurseries behaved in much the same way.

Samples of these plants taken at planting time were examined by the late Dr. Rayner and Dr. Levisohn, who found normal mycorrizha only in the Sitka

spruce and Scots pine seedlings from the New Nursery, and the Scots pine transplants from the Old Nursery. As far as these observations go there seems to be little relationship between compost, mycorrhiza and forest performance.

If the mycorrhizal equipment of seedlings influences forest performance, it might be expected that seedlings raised on formalin-treated soil might differ from those on untreated soil. In any event, since formalin allows usable seedlings to be raised in established nurseries, it is important to obtain evidence about their survival and growth in forests. The results of such experiments after two seasons are given in Table 43. Plants raised on steamed or formalin-treated soil grew well in the forests. One-year seedlings from steamed or formalin-treated soil at Ampthill and Ringwood (both very poor nurseries) grew almost as tall in two years as one-plus-one transplants from Old Kennington.

EFFECT OF FORMALIN AND STEAM IN SEEDBEDS ON GROWTH IN FORESTS

Table 43 Seedlings and transplants planted 1950

Planted as	Height in inches			
			After two years in forest, 1951	
	As 1+0 Seedlings	As 1+1 Transplants	Cwm Ysgawen, Coed Sarnau	Riddings Wood, Kerry Forest
1+1 transplants *Ex Old Kennington*				
No formalin	1.07	4.7	7.4	15.3
Formalin	1.52	5.5	8.4	15.7
1+0 seedlings *Ex Ringwood*				
No formalin	0.86	—	6.8	8.1
Formalin	1.67	—	10.8	14.6
1+0 seedlings *Ex Ampthill*				
None	1.04	—	5.5	6.9
Steam	2.38	—	8.0	13.5
Formalin	2.13	—	8.1	12.2
Steam+formalin	2.63	—	9.1	15.3

In experiments planted early in 1950 in two forests in Central Wales, there were severe losses, largely through soil wash from the exposed furrows, perhaps with some frost-lift. The smallest plants suffered most, as might be expected. It does not, however, appear that size alone was the determining factor. The percentage of deaths are given in Table 44 in order of nursery heights. About 15 per cent of transplants from Old Kennington and Kennington Extension were lost in Cwm Ysgawen. Only negligible numbers on one-year seedlings from Ampthill, Wareham, Ringwood and Wytham (Oxford) Nurseries, but a high proportion of those from Kennington Extension, Bagley Wood and Old Kennington were lost. At Riddings Wood the transplants survived well, but losses were particularly severe for Bagley Wood and Old Kennington seedlings. Although such small seedlings would not be planted in practice, some of the experiments are of interest in showing that small seedlings from some of the nurseries could survive and grow well under very difficult conditions. There was no indication that survival depended in any way on whether the seedlings had been raised with compost or fertilizers.

PERCENTAGE DEATHS OF SITKA SPRUCE, 1951, AFTER TWO SEASONS IN THE FORESTS
Table 44

	Height in inches in nurseries		Percentage deaths 1951			
			Cwm Ysgawen		*Ridding's Wood*	
	Plants raised with:		Plants raised with:		Plants raised with:	
	Compost	Fertilizer	Compost	Fertilizer	Compost	Fertilizer
Planted 1950 *as:* 1+1 *transplants*						
Wytham	—	7.8	—	2	—	0
Bagley Wood	8.6	7.6	2	2	0	0
Wareham	6.2	7.4	2	0	1	0
Old Kennington*	—	5.5	—	18	—	1
Kennington Extension	5.3	5.3	15	12	2	3
Planted 1950 *as:* 1+0 *seedlings*						
Ampthill*	—	2.1	—	5	—	17
Wareham	1.9	1.8	2	2	12	11
Ringwood*	—	1.7	—	1	—	2
Wytham	—	1.6	—	4	—	17
Kennington Extension	1.5	1.4	41	30	19	20
Bagley Wood	1.6	1.2	23	30	34	38
Old Kennington*	—	1.2	—	49	—	37

In nurseries marked * formalin had been applied to the seedbeds

Forest Manuring Experiments

In forest manuring experiments started early in 1948 at Decoy Heath, Wareham, fertilizers applied shortly after planting had increased heights by the end of 1951 from 11 to 30 inches for Sitka spruce transplants, from 6 to 25 inches for Sitka spruce seedlings, from 17 to 46 for Scots pine transplants and from 14 to 36 for Scots pine seedlings. For all four kinds of plants superphosphate gave taller plants than equivalent amounts of Bessemer basic slag or Gafsa phosphate rock. There were negligible effects from "Nitro-Chalk" and potassium fertilizer.

In three other forests planted early in 1948 superphosphate increased growth of Sitka spruce seedlings and transplants. Potassium fertilizer increased heights of Scots pine seedlings and transplants on a thin sand over chalk in King's Forest.

Root Examination

At the annual meeting of the Sub-Committee in October 1951, there was a long discussion on possible methods of characterising the root systems of plants raised in experimental plots and tested by forest plantings. Hitherto, a limited number of plant samples had been examined each season by Dr. Levisohn for mycorrhiza and pseudomycorrhiza, and a large number of samples has been weighed and subjected to chemical analysis at Rothamsted, where attempts had also been made to record empirical observations on crude morphological characters of the roots. Our observations led to the suggestion that a fine fibrous root system might result from damage to the main tap-root and laterals, and thus be a sign of lack of vigour. This view is opposed to an opinion commonly held among foresters, and it was therefore suggested by the late Professor F. T. Brooks that some batches of one-year Sitka spruce seedlings from contrasted treatments in several nurseries should be sent under code to a forthcoming Foresters' Course and that each forester should be invited inde-

pendently to record his opinion of them. Each batch was taken from a single plot in an experiment and does not necessarily represent the treatment tested. Details of treatments other than formalin are therefore not stated in Table 45. The samples were classified by 25 foresters at Northerwood House and then by 19 members of the Alice Holt staff.

CLASSIFICATION OF SITKA SPRUCE SEEDLINGS BY VISUAL JUDGMENT

Table 45

	Code Letter	Number of placings in classes					Mean Scores†		
		Very good 5	Good 4	Medium 3	Poor 2	Very poor 1	Northerwood Foresters 25 judges	Alice Holt Staff 19 judges	Panel of 4 selected judges
Bagley Wood	C	13	14	11	3	4	4.3	2.9	1.2
	I	10	15	12	5	3	3.9	3.2	1.8
	B*	25	16	4	0	0	4.4	4.6	4.0
	H*	12	26	7	0	0	4.2	4.0	3.2
Wareham	K	0	7	18	18	2	2.7	2.6	2.5
	F	0	6	24	13	2	2.8	2.6	2.5
	G*	5	19	17	3	1	3.3	3.7	4.0
	O*	1	12	20	12	0	2.9	3.2	3.2
Kennington Extension	E	5	22	11	7	0	3.7	3.4	3.2
	N	2	11	21	9	2	3.2	2.8	2.8
	L*	12	23	10	0	0	4.0	4.0	4.8
	A*	4	13	15	11	2	3.3	2.8	2.8
Ampthill	D*	10	15	14	6	0	3.5	3.8	3.8
Old Kennington	M*	6	18	15	6	0	3.7	3.3	2.8

*From plots which had received formalin.

†Calculated by allowing 5 points for a "Very good" placing, 4 for a "Good", and so on.

Note: The Panel of four selected judges included 3 of the Alice Holt judges and one chemist from the Rothamsted staff. Altogether 45 judges took part in the test.

The results in Table 45 show how many judges placed each sample in five classes from "Very good" to "Very poor" and the mean scores by three groups of observers.

There was a fair measure of agreement, Bagley Wood plants being generally ranked high and Wareham ones low. There were, however, a few striking discrepancies, especially with the Bagley Wood plants grown without formalin (Samples C and I). Most of the foresters ranked these among the best, but four other judges (three sylviculturists and one chemist who had taken part in the Sub-Committee's discussion at Northerwood House and who therefore knew some of the points at issue) classed them as the worst. Some individual comments on the Bagley Wood plants without formalin were: "Ideal root system", "Slightly pathological", "Horrid, black, unhealthy appearance".

It appeared that foresters attached high value to the predominance of fine, fibrous roots in these samples, but a few officers of the Research Branch shared our suspicion that this kind of root system was pathological. Plants with stout straight tap roots and thick laterals may be more troublesome to plant but they will probably anchor themselves and start to grow more quickly than those with fine fibrous roots. The characterisation of experimental planting material seems to call for systematic observations by botanists if full value is to be obtained from current investigations on nursery treatments in relation to forest performance.

EFFECT OF PARTIAL STERILIZATION BY STEAM OR FORMALIN ON DAMPING-OFF OF SITKA SPRUCE SEEDLINGS IN AN OLD FOREST NURSERY

By DR. J. H. WARCUP
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Three species of *Pythium*, including *P. ultimum*, isolated from soil of an alkaline old-established nursery at Ampthill, have been found to be parasitic to Sitka spruce seedlings. Symptoms varied from typical damping-off to a slow root-rot. Field study suggests that not all infected seedlings die, but some may survive as stunted plants with partly diseased root systems. Pathogenic *Pythium* species were common in nursery soil at Ampthill, but absent from forest soil there. *P. ultimum* was abundant in soil from three alkaline nurseries (pH 6.8-7.2) including the one at Ampthill, and rare or absent in soil from two acid nurseries (pH 5.3-5.5). In nursery sections of different ages at Kennington, *Pythium* species (pathogenic and non-pathogenic) were more abundant in the old than in the newer sections.

The effect of partial sterilization in nursery plots at Ampthill was, in part, to destroy pathogens. There was no evidence that *Pythium* species survived either the initial steam or formalin treatment, and subsequent recolonization of treated soil has been slow. Formalin has been found to be highly toxic to *Pythium* species in agar cultures and in soil. *Trichoderma viride* was often the dominant recolonizer of formalin-treated soil; experiments have shown that *T. viride* is more tolerant of formalin than are most other soil fungi.

Steam or formalin treatment markedly improved numbers and height of Sitka spruce seedlings in the first year after treatment, showed a moderate residual effect in the second year, but gave little improvement in the third year.

RESEARCH INTO THE PHYSICAL AND CHEMICAL PROPERTIES OF FOREST SOILS

By P. J. RENNIE
Department of Forestry, Oxford University

Physical Investigations: Porosity and Aeration

By July, 1951, the field work of the initial part of this investigation was concluded. Continued observations over four seasons were completed on the fluctuations of aeration and moisture content of natural *Calluna vulgaris* moorland, deeply ploughed moorland, and twenty year old Sitka spruce plantation. Likewise, data illustrating the annual fluctuations of these factors over almost all the soil types of the Allerston area supporting natural vegetation, deeply ploughed and "reclaimed" moorland, were available.

The laboratory work at Oxford associated with this investigation is nearing

completion, and steady progress is being made on the digestion and interpretation of the data. So far the data has shown:

(*a*) The *Calluna* peat overlying all geological types remains waterlogged for a considerable part of the year, the aeration only increasing for prolonged dry periods.

(*b*) Peat supporting *Eriophorum* and to a lesser extent *Erica tetralix* is only slightly aerated during dry summer periods.

(*c*) Medium depth and deep single-furrow ploughing, whether carried out three or eleven years previously, possess the ability to provide highly aerated peat and soil horizons for tree rooting all the year round.

(*d*) "Reclaimed" moorland soils, which are known to support good tree growth, have a higher pore space and aeration at all horizons to 70 cm. (about 27 inches) depth, compared to natural moorland.

(*e*) Four tree species tested upon a moorland soil vary in their capacity to reduce the high moisture status in the following decreasing order: Japanese larch, *Pinus contorta*, Sitka spruce, birch.

Rooting Investigations

The interpretation of this project, which was undertaken in relation to moisture studies (briefly mentioned in last year's report), has now been completed. As may be seen from the related diagrams many interesting contrasts have become apparent. (Each curve represents the mean of five soil profiles). Some noteworthy aspects are:

(*a*) the tendency of older *Calluna* (last burned thirty years ago) at Wykeham, Allerston Forest, to form a secondary zone of rooting just above pan level, in addition to the outstandingly high "root density" in the peat horizon. (Fig. 6). This tendency is not apparent in the younger *Calluna*, last burned ten years ago.

(*b*) the ability of Corsican pine on a difficult Wold site at Scardale Forest, East Riding of Yorkshire (about 10 cm. (4 inches) of loam over a hard laminated chalk) to exploit the subsoil and eventually deepen the easily rootable soil depth. (Fig. 7).

(*c*) differences in density and distribution of roots between various tree species in Experiments 11 (Fig. 8) and 6 (Fig. 9) respectively at Wykeham, Allerston Forest, due partly to differences in depth of ploughing, and partly to site differences.

In Experiment 11, Sitka spruce and birch appear much less able to penetrate to below 50 cm. (20 inches) than Japanese larch or *Pinus contorta*, and all species appear to develop a zone of maximum rooting correlated with the old heather peat buried by ploughing.

(*d*) basic slag applied to Sitka spruce in Experiment 11 appears to increase "root density" twofold in the 0-30 cm. (0-12 inches) zone but five fold in the 40-50 cm. (16-20 inches) zone (Fig. 10). The ability of slag to deepen the rooting zone in this very stony subsoil is a factor of importance in drought years when the main root system of most species would be confined to a zone of depleted water reserves.

(*e*) the variability of rooting of Sitka spruce according to soil type. The "root densities" for Sitka spruce in Brown Earth soils (Bakers Warren and Skellers Garth) steadily decrease with depth. This steady decrease is distorted when a humas pan (Sutherbruff Rigg) or buried peat (Wykeham Low Moor, Experiment 6) is present (Fig. 11). Considerable distortion is apparent for Japanese larch on medium depth single-furrow ploughing (Brompton Moor) where rooting reaches its maximum development in the old peat horizons (Fig. 12).

Growth of Sitka spruce in Relation to Cultivation (Experiment 52 Silpho Moor)

The assessment data for the first three seasons growth (*a*) on deep (13 inch) single furrow ploughing, (*b*) deep (5 inch) rotary hoeing, (*c*) shallow (1-2 inch) rotary hoeing, has now been analysed. Deaths on deep ploughing occurred during the first season only and were less than 1 per cent. Subsequent growth has been satisfactory, a superimposed heather mulch on certain plots giving a small increase in growth.

Deaths on shallow cultivations were observable during the first season, and continued throughout the subsequent seasons. Growth was unsatisfactory and weeding or mulching has failed to improve growth, in fact, mulching has depressed growth in many plots. It can be seen therefore that the principal value of deep ploughing is not solely the suppression of heather; the mere suppression of heather will not always make Sitka spruce grow.

For certain shallow cultivation plots a contour map of the absolute ironpan level has been prepared. Over 17 per cent of the area, the ironpan is in the form of closed basins from which there can be no lateral drainage. A further 15 per cent of the area may be classified as almost equally badly drained peripheral zones to the basins above. Deaths occurring in the first three seasons within the closed basins (i.e. the 17 per cent) amount to 48 per cent, elsewhere to only 17 per cent.

FIG. 6.

ROOT "DENSITY FUNCTION" IN RELATION TO SOIL HORIZONS

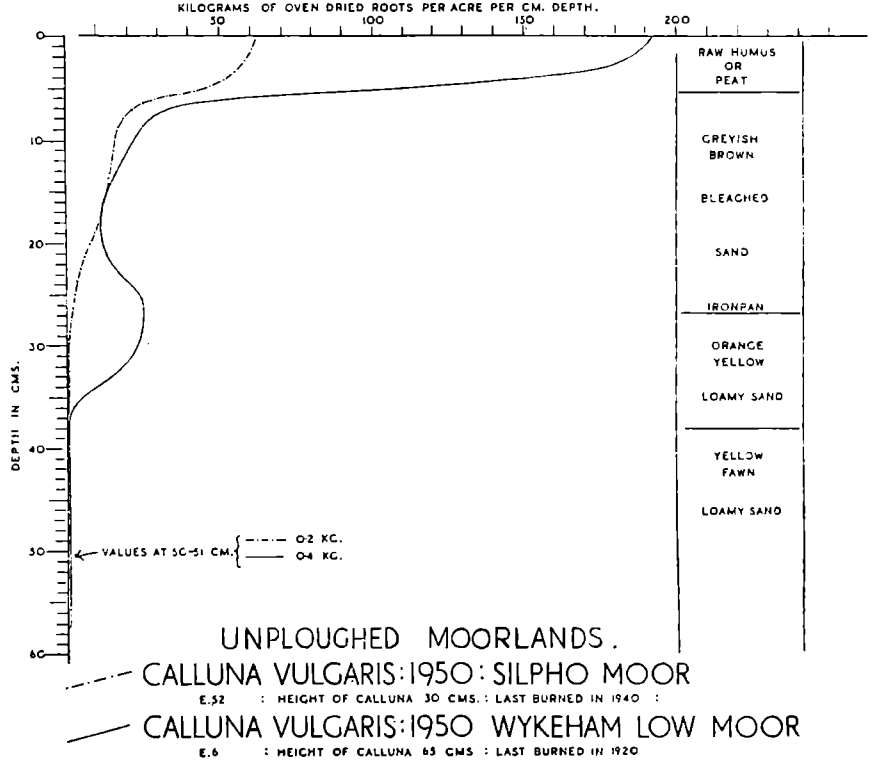
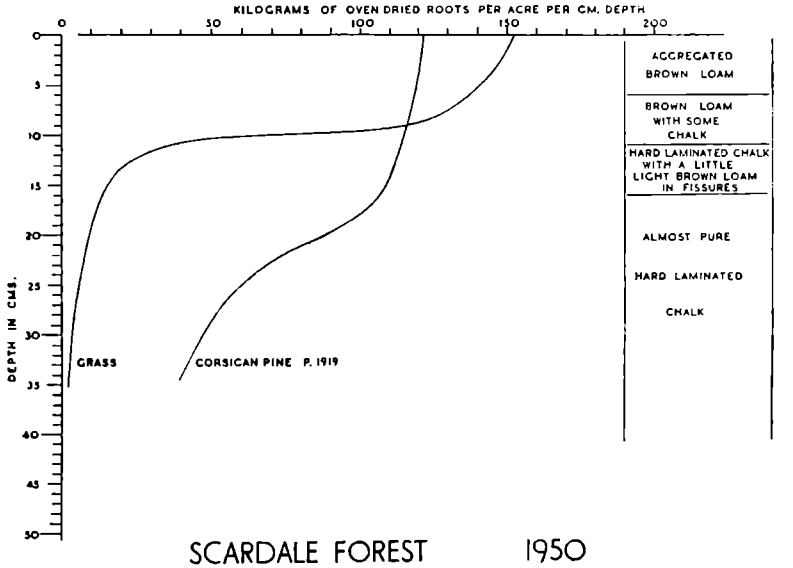


FIG. 7.

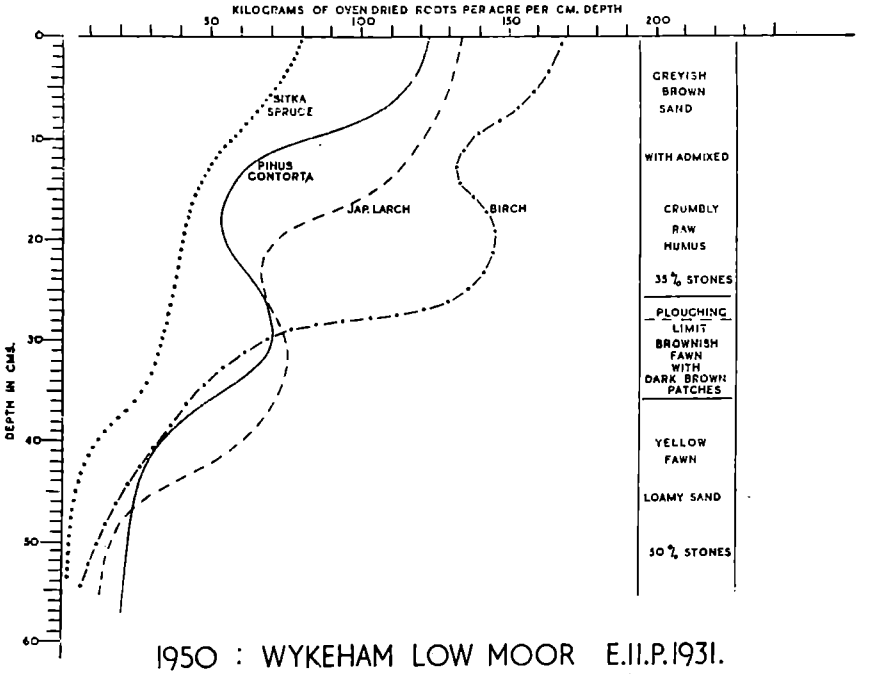
ROOT "DENSITY FUNCTION" IN RELATION TO SOIL HORIZONS



SCARDALE FOREST 1950

FIG. 8.

ROOT "DENSITY FUNCTION" OF DIFFERENT TREE SPECIES



1950 : WYKEHAM LOW MOOR E.11.P.1931.
MEDIUM DEPTH COMPLETE PLOUGHING.

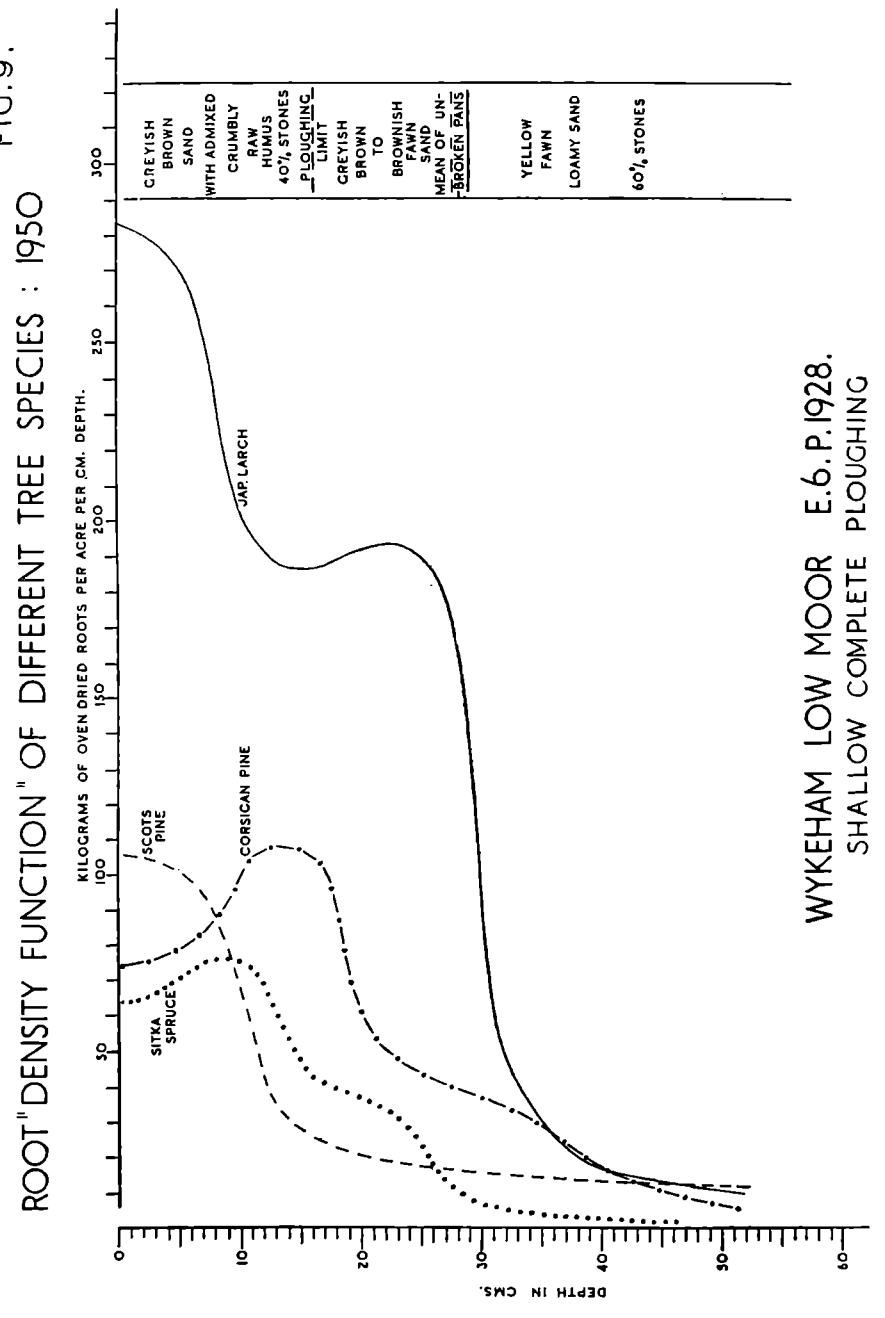


FIG. 9.
ROOT "DENSITY FUNCTION" OF DIFFERENT TREE SPECIES : 1950
KILOGRAMS OF OVEN DRIED ROOTS PER ACRE PER CM. DEPTH.
30
100
150
200
250
300
DEPTH IN CMS.
0
10
20
30
40
50
60
SITKA SPRUCE
SCOTS PINE
CORSICAN PINE
JAP. LARCH
GREYISH BROWN SAND WITH ADMIXED CRUMBLY RAW HUMUS 40% STONES
PLOUGHING LIMIT
GREYISH BROWN TO BROWNISH FAWN SAND MEAN OF UNBROKEN PANS
YELLOW FAWN LOAMY SAND 60% STONES
WYKEHAM LOW MOOR E.6.P.1928.
SHALLOW COMPLETE PLOUGHING

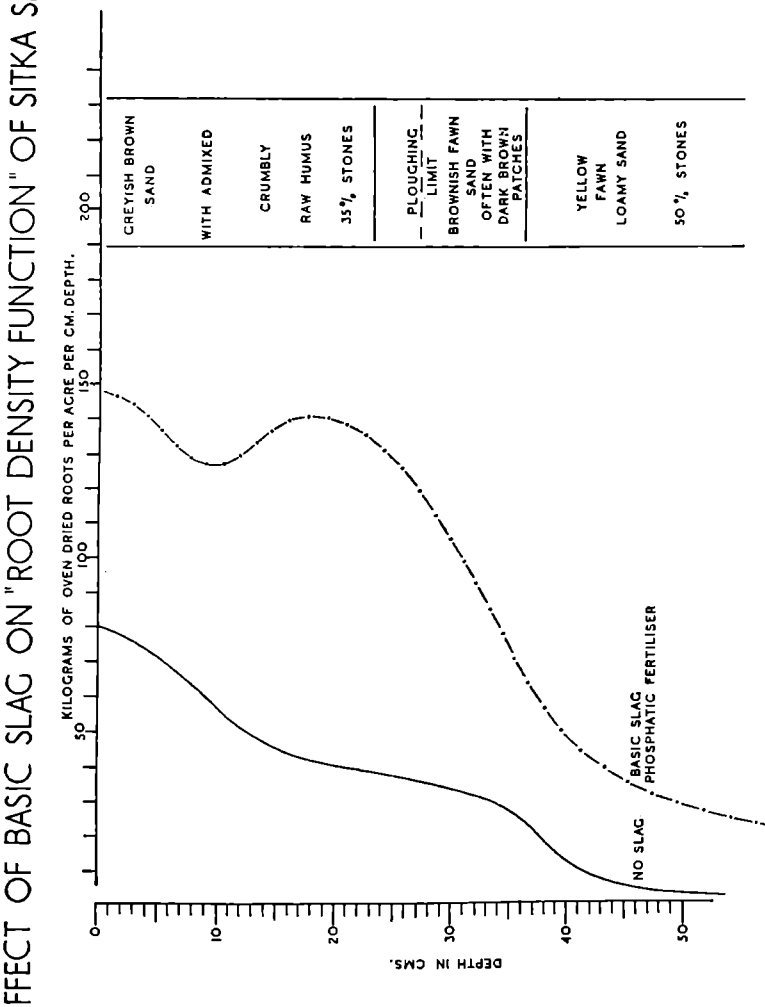


FIG. 10.
EFFECT OF BASIC SLAG ON "ROOT DENSITY FUNCTION" OF SITKA SPRUCE
KILOGRAMS OF OVEN DRIED ROOTS PER ACRE PER CM. DEPTH.
50
100
150
200
DEPTH IN CMS.
0
10
20
30
40
50
NO SLAG
BASIC SLAG PHOSPHATIC FERTILISER
GREYISH BROWN SAND
WITH ADMIXED
CRUMBLY
RAW HUMUS
35 % STONES
PLOUGHING LIMIT
BROWNISH FAWN SAND
OFTEN WITH DARK BROWN PATCHES
YELLOW FAWN LOAMY SAND
50 % STONES
1950 WYKEHAM LOW MOOR E.11.P 1931
MEDIUM DEPTH COMPLETE PLOUGHING.

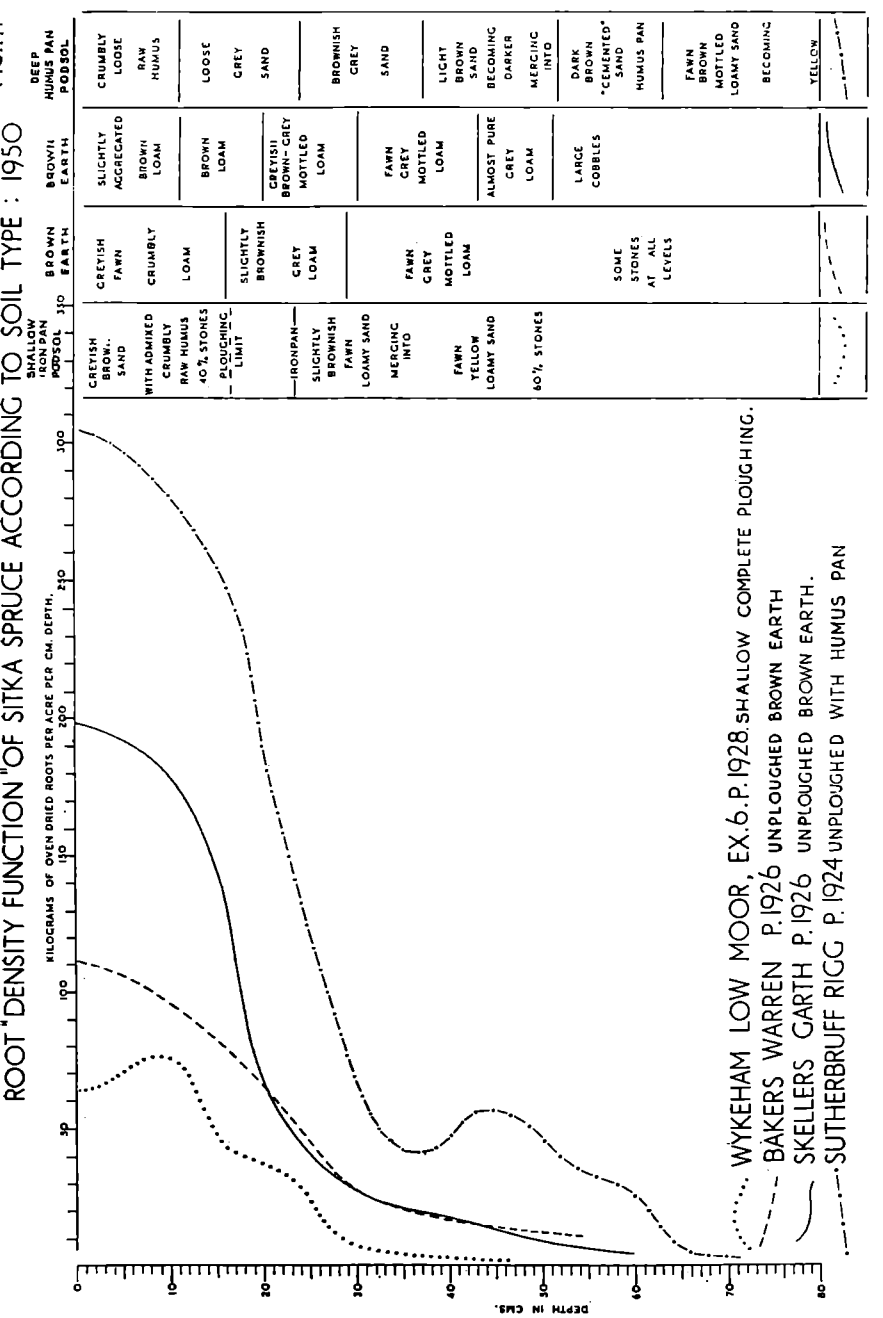
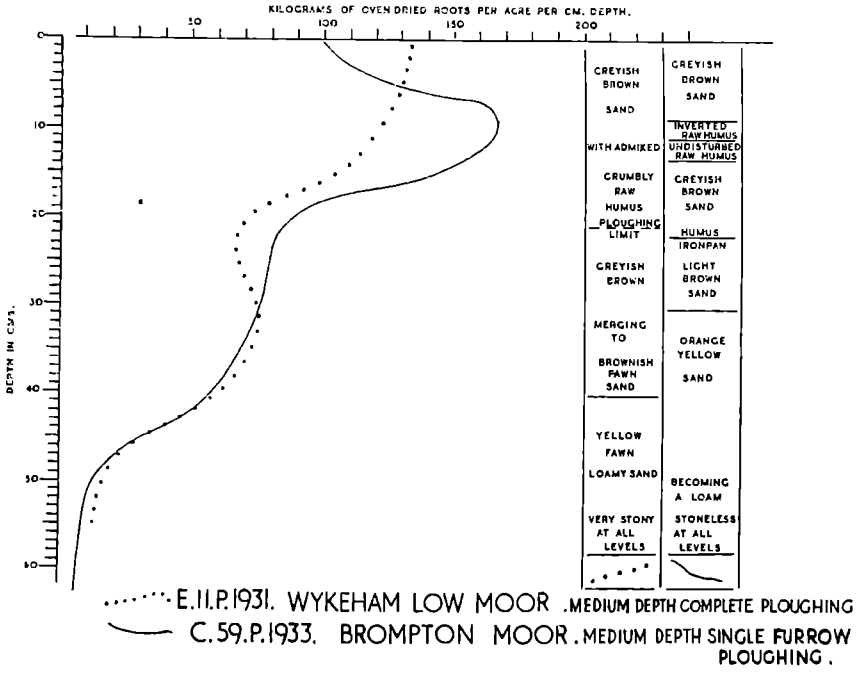


FIG.11.
ROOT "DENSITY FUNCTION" OF SITKA SPRUCE ACCORDING TO SOIL TYPE : 1950
SHALLOW IRON PAN PODSOL
BROWN EARTH
BROWN EARTH
DEEP HUMUS PAN PODSOL
GREYISH BROWN.. SAND
WITH ADMIXED CRUMBLY RAW HUMUS
40 % STONES
PLOUGHING LIMIT
IRONPAN
SLIGHTLY BROWNISH FAWN LOAMY SAND
MERGING INTO
FAWN YELLOW LOAMY SAND
60 % STONES
GREYISH FAWN
CRUMBLY
LOAM
SLIGHTLY BROWNISH
GREY LOAM
FAWN GREY MOTTLED LOAM
SOME STONES AT ALL LEVELS
SLIGHTLY AGGREGATED
BROWN LOAM
BROWN LOAM
GREYISH BROWN-GREY MOTTLED LOAM
FAWN GREY MOTTLED LOAM
ALMOST PURE GREY LOAM
LARGE COBBLES
CRUMBLY LOOSE
RAW HUMUS
LOOSE
GREY
SAND
BROWNISH GREY
SAND
LIGHT BROWN SAND
BECOMING DARKER
MERGING INTO
DARK BROWN "CEMENTED" SAND
HUMUS PAN
FAWN BROWN MOTTLED LOAMY SAND
BECOMING
YELLOW
KILOGRAMS OF OVEN DRIED ROOTS PER ACRE PER CM. DEPTH.
DEPTH IN CMS.
WYKEHAM LOW MOOR, EX.6.P. 1928. SHALLOW COMPLETE PLOUGHING.
BAKERS WARREN P.1926 UNPLOUGHED BROWN EARTH
SKELLERS GARTH P.1926 UNPLOUGHED BROWN EARTH.
SUTHERBRUFF RIGG P.1924 UNPLOUGHED WITH HUMUS PAN

FIG. 12

ROOT "DENSITY FUNCTION" OF JAP. LARCH ACCORDING TO SOIL TYPE: 1950



Limestone Experiment, Springwood Spur, Silpho Moor

An experiment incorporating coarsely ground oolitic limestone, applied to uncultivated, deep complete and deep single furrow ploughed *Calluna* moorland has recently been commenced. Two species, Sitka spruce and sessile oak, are used separately, and unplanted controls are included.

It is known that these *Calluna* moorland soils are extremely deficient in available nutrients; the object of this experiment is to find out whether by employing a combination of deep single-furrow or deep complete ploughing with a slowly weatherable limestone this deficiency may be corrected to allow for higher rate of tree growth.

Good progress has been made on the investigations of base exchange of representative soils of the Allerston area. The main emphasis so far has been on reliability and suitability of methods, but certain notable features of the data are already apparent:

(*a*) the extremely low nutrient levels of all horizons for all moorland soils, but the variability between them.

(*b*) the higher available nutrient content of the *Calluna* peat relative to all deeper horizons.

(*c*) the higher available nutrient levels for soils which are supporting good quality Sitka spruce, whether "reclaimed" from moor or on better geological strata.

(*d*) the rapid removal of calcium from the upper mineral soil horizons under good quality Sitka spruce, and its partial accumulation in the litter.

Work on soil phosphorus has been started. One method of analysis has been successfully adapted to a micro-scale and used for the determination of the phosphorus content of some Allerston soils.

Historical Land-use Maps

These six-inch maps covering the whole of the Allerston and Langdale Forests have been completed. All forest compartments are shown, together with the areas of the land used for agricultural or forestry purposes both up to 1854 and after 1854. Soil profiles have been drawn, and much quantitative physical and chemical data is available for representative sites illustrated on the maps. These are, of course, primarily afforested areas.

Although agricultural land in 1854 was confined essentially to the better geological types, considerable "conversion" of moorland to agricultural soils on poor geological types has occurred in some localities since 1854, notably in the Harwood Dale area.

The maps have been invaluable for accurately recording the history of sampling sites, where failure to take into account previous land use can lead to erroneous conclusions. For example: (*a*) improved growth of Japanese larch on parts of Brompton Moor has been traced to the sites being arable land for a considerable period before afforestation; (*b*) natural regeneration of oak and birch within certain plots of E.11 Wykeham appears to be related more to the position of stumps of Scots pine growing in 1920 than to the present tree crop planted in 1928.

THE INFLUENCE OF TREE GROWTH ON SOIL PROFILE DEVELOPMENT

By T. W. WRIGHT
Macaulay Institute for Soil Research, Aberdeen

Nitrification Studies

The main work of the past year has been the study of nitrite and nitrate formation in soils percolated with ammonium sulphate solution in the Lees apparatus. Nitrification was observed in samples of surface soil from the Norway spruce sample plots at Bowmont Forest, Roxburghshire, and from the beech-ash-sycamore association of Dunnottar Forest, Kincardineshire. In all cases it followed the familiar pattern reported by Lees and others for agricultural soils, namely an initial production of nitrite after a short lag period, followed by the appearance of nitrate, building up to a maximum at the expense of nitrite formation, and finally declining under the influence of denitrification processes. The quantities produced, however, have been much less than those reported for the agricultural soils, and the method as applied at present to forest soils has been found to suffer from the following serious limitations:—

(1) No appreciable nitrate is produced at pH's below about 7.4, necessitating a considerable raising of pH of all samples of forest soil and consequent production of extremely artificial conditions.

(2) Nitrate production appears to be strongly influenced by relatively small changes in pH, and reproducibility of results has been poor.

For these reasons the use of this method has been discontinued, and it is proposed to use an incubation method for further work.

Work at Culbin Forest, Morayshire

A suitable bridge for measuring the resistance of the Bouyoucos gypsum moisture blocks installed in the sample plots at Culbin was obtained in time to take a short series of trial readings before the sand became saturated in the autumn. These confirmed that the apparatus is suitable for qualitative detection of water movement in the dunes, although, owing to the very low tensions at which moisture is held by the sand, reliable quantitative data can only be obtained by sampling and drying. A "Speedy" moisture tester is being used for this purpose.

In order to investigate further the cyclic movement of available nutrients taking place in the planted areas, the litter fall on the sample plots is being collected at bi-monthly intervals by means of a number of shallow wooden trays, and its weight and nutrient content is being determined on a statistical basis.

Other Work

Preparations are being made to study a new radioactive method of soil moisture determination recently developed by Canadian and American workers, which depends on the slowing down of fast neutrons emitted from a source by the hydrogen in the water molecules, and their subsequent detection and counting by a combination of a Geiger counter and a metal screen. It is hoped that this method will prove independent of soil type or texture.

GROWTH AND NUTRITION IN HEATHLAND PLANTATIONS

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

Investigations continue into the growth and mineral nutrition of Sitka spruce and pine planted on *Calluna* heathlands. In June 1949, plots were laid out to test the effects of heather removal (screefing) and the application of various levels of ground mineral phosphate (0 to 6 oz. per tree) in an eight-year-old plantation of Sitka spruce and Corsican pine in Yorkshire (Wykeham Moor, Allerston Forest) and of Sitka spruce and Scots pine of similar age in Scotland (Clashindarroch Forest). In both areas the spruce were in partial or complete check. At the end of the 1949, 1950 and 1951 growing seasons, growth assessments were made and analyses carried out on current years needles sampled from lateral shoots. Enough data have been collected to give some insight into the phenomena associated with the checking of spruce by the heather and the effect of phosphatic fertilizers on these soils.

Tree growth assessments are normally based on annual height increment. Within the range of ages, height, and conditions dealt with, it was found that, independent of treatment, the annual height *increment* of a tree was directly proportional to its height. Since in these experimental areas, tree heights varied considerably from plot to plot, the evaluation of growth responses has been based, not on increment alone but on a so-called relative increment value, i.e. the annual height increment adjusted to the height of the tree at the end of the previous growing season.

Wykeham Moor, Allerston Forest

Sitka Spruce. At the end of the 1949 growing season, approximately five months after treatment, screefing had already led to significant changes in the potassium, calcium and manganese status of the needles, and the various phosphate applications had resulted in significant changes in their phosphorus status; but no corresponding changes in growth were observed. In 1950, the trees on the screefed plots were of a very much improved colour, their needles were significantly higher in dry matter, and they contained about double the amount of nitrogen compared with needles from the trees on the non-screefed plots. In spite of these changes, growth on the screefed plots was significantly poorer than on the non-screefed plots—possibly the trees were affected by drought conditions following the removal of the heather the previous dry year. In 1951, however, the growth of the trees on the screefed plots was significantly higher, the difference between average height increments for "screefed" and "non-screefed" trees of the same height amounting to almost six inches. Growth on the screefed plots was also increased where phosphate had been applied, but though this was associated with the higher phosphorus contents in the needles, the absence of a significant correlation between growth and the phosphorus status of the needles suggests that the phosphorus nutrition of the trees is not the controlling factor. A significant relationship between the phosphorus and nitrogen status of the spruce needles suggests instead that the phosphate is in some way stimulating the nitrogen uptake by the tree. Thus it is possible that the ground mineral phosphate exercises an indirect influence on tree growth either by stimulating root growth or microbiological activity in the soil. It is interesting to note the very much reduced phosphate influence on the growth of the trees in the presence of the heather.

The marked rise in the nitrogen status of the needles following screefing, and the improved growth of the trees in the following year, suggest that much of the "*Calluna* effect" can be interpreted in terms of nitrogen nutrition. In the presence of heather, significant relationships have been established between height increment and the concentration of nitrogen in the needles, suggesting that growth is limited by the availability of this nutrient. This is supported by the fact that other measures which have stimulated the growth of spruce on these heathlands (e.g. mulching or the application of nitrogenous fertilizers) have also led to increases in the nitrogen status of the needles. Though the trees on the screefed and non-screefed plots showed such marked differences in growth in 1951, there is little difference in the nitrogen contents of their needles, and it therefore remains to be seen whether these differences in growth will be maintained in 1952.

Corsican Pine. The response of the pines to treatment has been much less than the spruce. The data on pine have not yet been worked up in detail, but in 1950 the needles of the pines on the screefed plots showed a significant increase in dry matter and nitrogen content over the non-screefed pine needles, and the difference was maintained in the 1951 samples. Phosphate applications also appear to be having some positive effect on the dry weights of the needles, but no figures are yet available as to the significance of these changes in terms of tree growth.

Clashindarroch Forest

Sitka Spruce. The trees at Clashindarroch were very much more checked than those at Wykeham Moor, and the resulting growth reponses have been

much more difficult to assess. The changes brought about by screefing and phosphate fertilizing however are very similar to those at Wykeham Moor, except that they have been much less marked. In all three samples (1949, 1950 and 1951) the phosphate content of the needles has revealed significant changes with increasing applications of fertilizer, and again in 1950 and 1951 screefing has resulted in significant increases in the nitrogen status of the needles. There appears to have been a similar reponse in the height increment growth of the trees, but statistical analysis of the results has not yet been completed.

Scots Pine. The results obtained so far suggest responses very similar to those of the Corsican pines, i.e. increased phosphorus contents of the needles, with phosphatic fertilizing, and increased nitrogen contents with screefing.

RESEARCHES IN SOIL MYCOLOGY

By Dr. IDA LEVISOHN
Bedford College for Women, London University

Mulching

Investigations concerned with the effect of pre-mulching of seed beds and mulching in the field were continued. In experiments at Sugar Hill Nursery, Wareham Forest, Dorset (Expt. War. 21 P. 51 and others), sowings on pre-mulched ground produced one-year seedlings of *Pinus contorta* and Sitka spruce which, in height and vigour, were practically indentical with seedlings raised on composted soil. While, as usual, controls of *P. contorta* possessed mycorrhizas of a subnormal type and controls of Sitka were non-mycorrhizal, both *P. contorta* and Sitka spruce from plots which had been pre-mulched were well equipped with normal mycorrhizas (like the seedlings from the composted plots).

It is of interest that pre-mulching without further treatment produces satisfactory seedlings although, according to soil analyses, there is no increase in available phosphate during and after the period of mulching.

New experiments of mulching plants in the field provided additional evidence of the striking effect of mulching on shoot and root improvement, as described in the *Report on Forest Research for* 1951. It is difficult to assess the time factor concerned in the effect on shoot and root, i.e. to determine which occurs first, improvement in shoot development or in root condition. The problem has been approached tentatively by systematically recording the development of root and shoot in control and mulched plants. In cases where mulching was started during the summer, the changes in root conditions were observed before improvement in shoot development was noticeable "externally".

In order to assess the rôle of available potash supplied by organic mulches like fresh bracken, treatments with sulphate of potash were included in a planting experiment with Lawson cypress (Expt. 99 P.51). After seven months of application, the effect on shoot and root conditions was obvious on the mulched plants only, while plants from potash treatments were indentical with control plants.

Forking and Infection in Pine Roots

Pot experiments have been carried out with the object of studying the separate phenomena of root forking and root infection in the genus *Pinus* and, through such analysis, to determine the rôle of actual mycorrhizal infection in the life of the host plants.

Pots with actively growing pine seedlings were fitted in the necks of earthenware jars, and the leaching water allowed to accumulate in these containers. The roots growing from the bottom of the pots into the leaching water below were examined and the following facts observed:

(1) When the seedlings in the pots had no root associations (i.e. in sterilized soils), the roots submerged in the leaching water did not fork (nor was there any root infection present).

(2) When the seedlings in the pots were mycorrhizal, the submerged roots were profusely forked but did not show any infection. This result conforms with Slanki's observations on excised pine roots, that forking of the short root system can be produced by exudates of mycorrhizal mycelia.

(3) When the seedlings in the pots had haustorial root infection, the submerged roots showed a fair amount of forking with deep haustorial infection.

From these results it would appear that not only mycorrhizal fungi but also the fungi responsible for haustorial infection can induce forking of the short root system. As regards the haustorial infection, the foregoing experiments supply additional evidence that this type of intracellular infection, as occurring in this country, is an infection *sui generis* and not a "converted" mycorrhizal association.

MORPHOLOGICAL VARIATIONS IN CONIFEROUS SPECIES

By DR. E. V. LAING
Department of Forestry, Aberdeen University

Research has continued along the following main lines—(1) the identification of hybrid larch in the very young seedling stages; (2) a study in the variations of Japanese larch; (3) the identification of European larch races by means of cone and seed; (4) the morphological distinction between *Pinus contorta* and *P. murrayana.*

From the data now available it is considered possible to state the proportion of hybrid larch in any sample of seedlings derived from Japanese larch mother trees. The determination of seedlings derived from European larch mother trees still presents great difficulty. The determination lies in the structure of the cross-section of the cotyledons of the newly germinated seedling. The hybrid larch cotyledon shows mainly European characters in respect of endodermis, epidermis and sclerenchyma formation. It is found that if suspected hybrid larch seed is tested a proportion is true Japanese, some have intermediate characters and some have predominantly European larch characters. There would thus seem to be two hybrids apparent even at this early stage—one which

is very near European and one which is intermediate. This is what is found in bigger trees. The test takes from three to four weeks as the seed has to be first germinated.

Colour tests have been made but so far no colour reaction has been found to be entirely satisfactory.

The variation in cone structure in Japanese is being found to be almost as great as in European larch. The variations are being described in the same way as for European larch.

The botanical differences between shore pine and the lodgepole pine have been studied in more detail and are being found to be sufficient to define them as distinct species, namely *Pinus contorta* and *P. murrayana*. Differences exist in respect of seed size and colour and surface texture, number and length of cotyledons, serrations and apices of primary leaves, leaf anatomy and bark. The timber shows anatomical differences which are being investigated.

A STUDY OF THE NATURAL PINEWOODS OF SCOTLAND

By A. CARLISLE

Department of Forestry, Aberdeen University

This study has been in progress since the 1st January, 1950, and research has been on two distinct but related subjects, as set out below:

Morphological and Silvicultural Variations of the Native Scots Pine in Scotland

First of all the variations of individual morphological characteristics within single stems were studied. Ten trees were felled in a planted wood at Dalliefour, Alltcailleach Forest, Aberdeenshire, and each tree subjected to an intensive analysis. Sample shoots were taken at various heights and aspects in the crown, and their morphology and anatomy studied. The data showed that the following features, although varying between trees, were relatively constant within individual trees:

Cone form	Bud form and colour
Apophysis development	Mean leaf length
Seed colour	Leaf colour
Seed wing form and colour	Leaf sclerenchyma development
Shoot colour	Leaf persistence

All other features were too variable to be of use as potential characteristics of strain. None of the variations occurring within trees showed any relation to either height or aspect.

Using this data as a guide to sampling methods, the variations of the morphological characteristics from tree to tree were studied in native pinewoods in different parts of Scotland. On the basis of this work and further investigations in certain natural pinewoods, the following characters were selected for detailed study:

Bark Type. At least three definite bark types were distinguished, together with a number of intermediates. An investigation was made of the correlation between bark type and age, increment and environment.

Crown form. The native Scots pine was found to exhibit a number of crown forms, some of which are probably genetic, but many are due to varying site factors.

Angle of Branching. Data collected from trees in isolated positions suggest that the native Scots pine has three types of branching angle.

Buds. Three bud forms have been recognised, and further studies as to the significance of the variation have been initiated.

Leaf Colour. In spite of the difficulties presented by the seasonal variations in leaf colour, it has been possible to distinguish three leaf colours that remain constant within individual crowns. The colour variation appears to be independent of age and environment. It is encouraging to note that a similar range of leaf colour has been observed in two-plus-one transplants grown from native seed.

Leaf Anatomy. This work is still in its early stages. At present the only feature to exhibit constancy within a single tree, and variation from tree to tree, is the development of the leaf sclerenchyma.

Cones. The cone is one of the most variable features of the native Scots pine. Six cone types, with intermediates, have been distinguished.

Female inflorescence. Two, possibly three, colour variations in the young (one-to-two week old) cones have been recognised.

Male inflorescence. Two colour variations, with one intermediate, have been differentiated.

Seed. Investigations are in progress into the significance of variations in seed form and colour.

Seed Wing. The seed wings from the native Scots pine exhibit variations in form and colour that are quite distinct. The seed wings are being classified on this basis.

Future investigations will be directed to considering whether or not there is any correlation between the individual characters, and whether this correlation exhibits a constancy that will permit the recognition of definite strains or varieties of the native Scots pine on a morphological basis.

Ecological Survey of Natural Pinewoods in Scotland

During the years 1950 and 1951, surveys were made of 42 reputed natural pinewoods. The areas visited were:

Achnacarry, Inverness
Achnashellach, W. Ross
Aigas, Inverness
Alladale, E. Ross
Amat, E. Ross
Ballochbuie, Aberdeen
Cannich and Mullardoch, Inverness
Cladich, Argyll
Coire Guibsachan, (Ballachulish) Argyll
Cougie, Inverness
Coulin and Loch Clair, W. Ross
Crannach, Argyll
Creagan, (Appin) Argyll
Doire Darach (Loch Tulla), Argyll
Fasnakyle, Inverness
Glen Affric, Inverness
Glen Einig, Ross
Glen Etive, Argyll
Glen Falloch, Perth
Glen Fuar (Loch Tulla) Argyll
Glen Garry, Inverness
Glen Loy, Inverness
Glen Mallie, Inverness
Glen Mor and Diebedale, E. Ross
Glen Moriston, Inverness
Glen Nevis, Inverness
Glen Orchy, Argyll
Glen Strae, Argyll
Glen Tanar, Aberdeen
Glenure, Argyll
Guisachan, Inverness

Leckmelm, W. Ross
Loch Arkaig, Inverness
Loch Awe Islands, Argyll
Loch Maree Islands, W. Ross
Loch Maree, South-east end, W. Ross
Rhidorroch, W. Ross
Strathfarrar, Inverness
Strath Oykell, Ross and Sutherland
Struy, Inverness
Torridon, W. Ross
Tyndrum, Perth

An investigation of these woods showed that some may be planted woodlands, or naturally regenerated from planted woods. As far as is known to date, there are still twenty-two woods to be investigated.

In each of the woodlands inspected the following data were collected:

1. The present woodland boundaries and corrections to the Ordnance Survey six inch to one mile maps.
2. Location, area, topography, elevation, aspect.
3. Geology, soils, drainage.
4. Communications.
5. Climatic data.
6. History.
7. The policy of the owners as regards the woods.
8. Reasons for the survival of the Scots pine.
9. Damage due to both biotic and physical factors.
10. Notes on the fauna, including the entomology.
11. The ecology of the marginal and extra-marginal communities.
12. The ecology of the main pinewoods and associated native broadleaved communities.
13. Stocking, distribution, and density of the pinewoods.
14. The occurrence of natural regeneration of Scots pine and the associated plant communities.
15. Plant list.
16. Fauna list.
17. Incidence of morphological variations in the Scots pine.
18. Quarter-girth at breast-height, height, increment and age of Scots pine.

In addition, a photographic record was made of each area. Specimen shoots and cones were collected for subsequent grafting and inspection of the morphological variations. Seed was collected from different types of Scots pine in native pinewoods in all parts of Scotland. During the tours of the pinewoods, trees of desirable form, or which appeared to be growing well in adverse conditions, were noted as potential sources of seed.

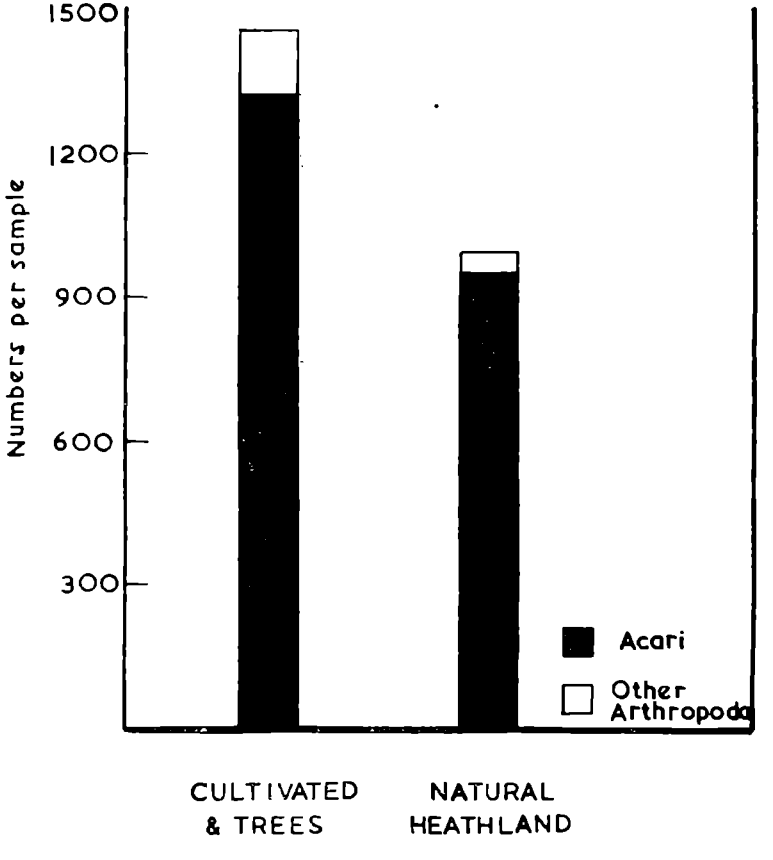
SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY
Rothamsted Experimental Station, Harpenden

The writer, whose present appointment at Rothamsted dates from July, 1951, has continued investigations of the animal biology of forest soils, investigations which had been initiated at the Department of Forestry, University of Oxford. The primary project in this study has been an examination of the soil Arthropod fauna of a heathland habitat in the Allerston Forest area, Yorkshire, before and after afforestation.

Considerable progress has been made in the examination and analysis of samples obtained in previous years. As a result it is now possible to give a broad outline of the faunal population occurring in natural and cultivated heathland. Figure 13 contrasts the total population of Arthropod organisms in natural heathland with that occurring in cultivated heathland planted with Sitka spruce (trees twenty years old and forming canopy). These populations represent 570,000 and 835,000 individuals per square metre respectively (2,305 and 3,380 million per acre). The vertical distribution of the fauna in both sites is illustrated in Figure 14. It will be noted that the population in the natural heathland is concentrated in the surface layers, 96 per cent of the total being present in the first $2\frac{1}{4}$ inches of the profile. The cultivated heathland with trees shows two zones: the litter layer on the surface where 40 per cent of the population occurs, and the raw humus "sandwich" formed in the ploughing process which contains 54 per cent of the population.

FIG.13. POPULATIONS OF SOIL ARTHROPODS IN HEATHLAND.



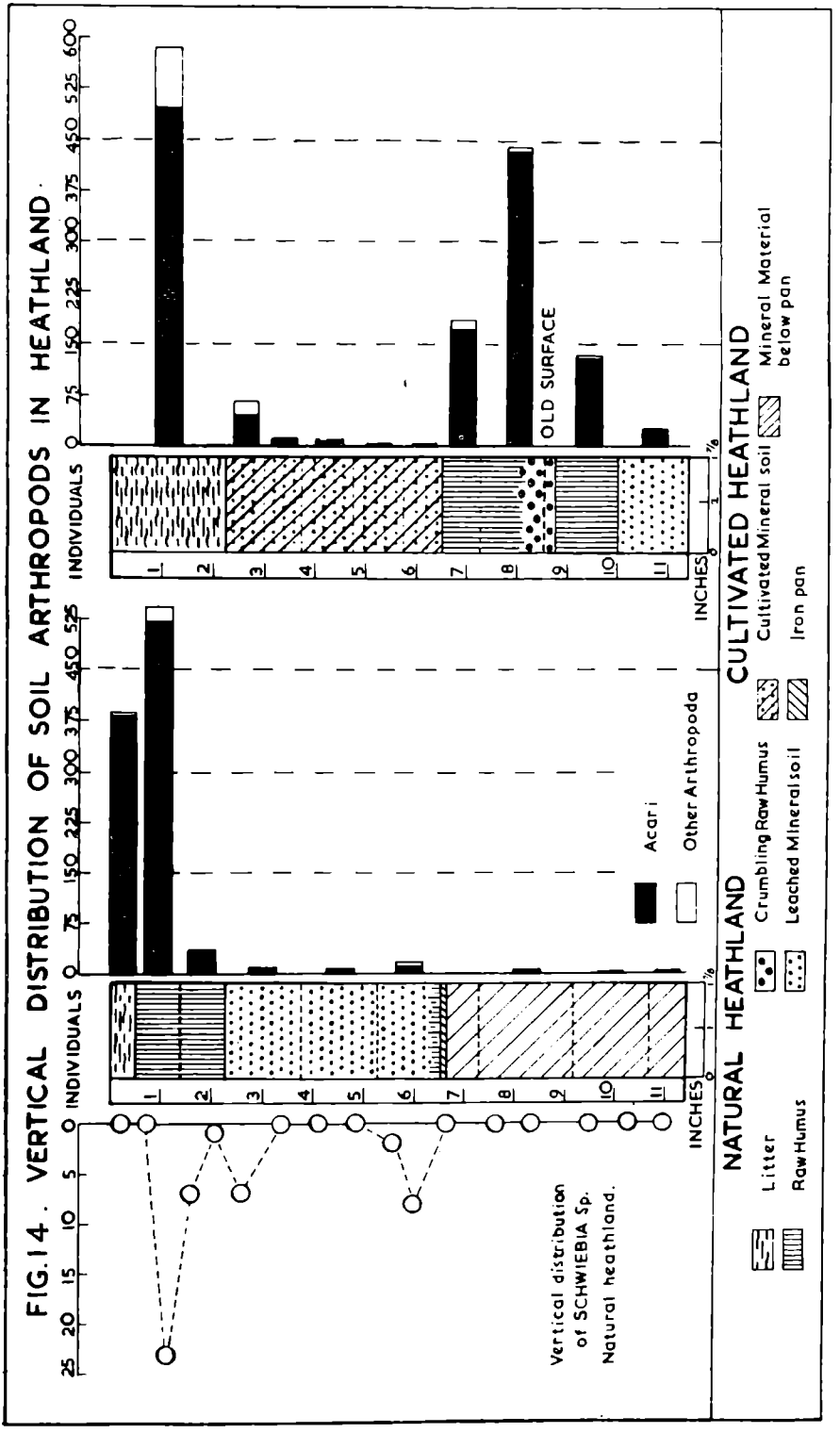


FIG.14. VERTICAL DISTRIBUTION OF SOIL ARTHROPODS IN HEATHLAND.
INDIVIDUALS
INCHES
%
OLD SURFACE
Acari
Other Arthropoda
NATURAL HEATHLAND
CULTIVATED HEATHLAND
Litter
Raw Humus
Crumbling Raw Humus
Leached Mineral soil
Cultivated Mineral soil
Iron pan
Mineral Material below pan
Vertical distribution of SCHWIEBIA Sp. Natural heathland.

QUALITATIVE STRUCTURE OF THE ARTHROPOD FAUNA OCCURRING IN HEATHLAND

Table 46

Sample type	Total population per sample (506 c.c.)	Acari per cent	Collembola per cent	Other Arthropoda per cent
Natural Heathland	998	95.2	3.8	1.0
Cultivated Heathland + Sitka Spruce	1,462	90.5	8.1	1.4

The qualitative structure of the population is indicated in Table 46 and Figure 14. The most striking feature is the preponderance of Acari in both habitats. However it would be unwise to draw too many conclusions from the data presented. In the first place the populations represented are those occurring in November, a time of the year when numbers tend to reach a peak. Further, owing to the great variation from sample to sample, these figures should be regarded merely as broad indications of the population structure. The Collembola figures are particularly subject to violent fluctuations from sample to sample, and it is probable that they are here represented by minimal values.

During the period under review most attention has been paid to the *Prostigmata* component of the *Acari* population, and identification of this most difficult systematic group has now reached the stage where the major genera and species are known. In the undistributed heathland the *Prostigmata* are dominant, but in afforested sites (trees in canopy) the *Oribatei* assume this role. The structure of the *Prostigmata* population is rather similar to the *Oribatei*. For example it is faunistically poor and is often dominated by one species, in some cases to the extent of almost complete exclusion of other members of this group. Much attention has been paid to changes brought about by cultivation, an essential process in this area if afforestation is to be successful, and as one would expect, considerable qualitative changes occur in the raw humus "sandwich" created by ploughing. For example, *Nanorchestes arboriger* Berl. (saltatorial and essentially a surface species), the most numerous Prostigmate species of the natural heathland, disappears, the *Oribatei* becomes dominant, and *Nanorchestes* appears to be replaced by *Alicorhagia fragilis* Berl. as the dominant *Prostigmata*. It is interesting to note that these two species belong to the same family *Pachygnathidae*.

In his report for 1951, the writer drew attention to the occurrence of a species of the *Acaridiæ* in natural heathland. This mite (*Schwiebia* sp.) is of interest because although forming only 5 per cent of the total population, its distribution shows a marked zoning in the profile. Figure 14 illustrates the vertical distribution of *Schwiebia* sp. and it will be noted that there are two peaks, one in the lower part of the raw humus horizon (just below the main faunal concentration), and the other in the organic material above the pan. At the second level this mite is virtually the only Arthropod representative.

There is little to report in the sphere of biological studies. Stock cultures of a number of *Acari* species have been maintained, and some experiments have been conducted to confirm earlier investigations of litter preferences of certain species. *Nothrus silvestris* Nic., one of the largest Oribatid species occurring in the natural heathland, has proved a voracious feeder on *Calluna* litter in culture, and when provided with *Calluna* and Sitka spruce litters, has shown a preference for the former.

RESEARCH ON MEGASTIGMUS INSECTS INFESTING CONIFER SEED

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

New locality records come to light mainly in the course of routine tests on seed at Alice Holt. It is proposed, however, to arrange for more widespread collections from larch and spruce when the cone crop makes this possible, as it is thought likely that *Megastigmus seitneri* and *M. strobilobius* Ratz. (=*M. abietis Seit.*) may be more widespread than present knowledge indicates. Ten localities have been selected for sampling of Douglas fir seed in order to provide data over a number of years on the manner in which the extent of infection by *Megastigmus* is affected by the size of the cone crop.

During the year the smaller form of *M. pinus* reared from *Abies grandis* at Evanton, Ross-shire (1951 Report) was identified as *M. milleri.* A single female *M. rafni* was obtained from Kincardineshire and *M. seitneri* from larch at Dunkeld and Bedgebury. *M. rafni* is very similar to *M. spermotrophus* but occurs only in the seed of *Abies* spp., whilst the latter is restricted to *Pseudotsuga* (cf. *Scottish Forestry*, 6.53.1952).

Three species of *Pteromalids* (*Chalcidoidea*) have been reared from seed infested by *Megastigmus* and indentified as *Amblymerus* (?) *apicalis* Thoms., *Anogmus* (?) *strobilorum* Thoms., and *Trichomalus* sp. near *sunides* Walk. *Amblymerus* was recorded from Evanton, Rosehaugh, and Glen Tress (Peebles-shire). Parasitism during the 1951 season reached approximately 50% at each locality. The parasite female lays her eggs at the end of October on the *Megastigmus* larva within the ripe seed; hatching occurs the following May, and the ectoparastic larvae consume the host larva within five weeks. Adult *Amblymerus* emerge about September, although some overwinter for a second year.

Details of the biology of *Megastigmus spermotrophus* have been worked out as follows:—

Adults appear over a period of a week in late May or early June, the males a day or so before the females; the only feeding activity observed took place on the excretions of the colonici of *Adelges cooleyi.* Fertilization occurs almost immediately after emergence, although facultative parthenogenisis is possible, and the eggs are ripe for laying within four days. At Bedgebury Forest, Kent, during 1951, an average of ten eggs per female were laid, although examination of the ovaries showed that they were apparently capable of laying many more. The eggs hatch within five days, and the five larval instars are completed in eight weeks, when they enter diapause for a variable period of up to two years. A number of experiments are in progress to determine the factors influencing the proportion of larvae overwintering for the extra year. At present it appears that the more moist the conditions under which the seeds are kept, the higher the percentage of *Megastigmus* which remains in diapause. This indicates that those seeds which fall from the cones will contain larvae which, owing to the moister ground conditions, will tend to remain without development for an extra year and hence be subject to control by birds and mammals for a longer period. Observations in progress tend to show that loss of seed by birds is very slight, Samples of litter show that about 30 per cent of naturally shed seed is damaged

by small rodents, but such an analysis does not take into account seed carried off to a store or consumed whole, although this may affect a considerable proportion, for seed lots artificially laid out usually show damage or loss amounting to 90 per cent.

Census studies on fecundity and all forms of mortality are continuing at Bedgebury and Evanton. The Forester Training Schools are co-operating in studies to determine exactly at which stage in the development of the cone oviposition is possible. Present information indicates that the cone is susceptible only for a week or so.

THE NESTING OF TITMICE IN BOXES

By DR. D. LACK
Edward Grey Institute of Field Ornithology, Oxford

The enquiry organised through the Edward Grey Institute of Field Ornithology, Oxford, on the nesting of titmice in nest boxes placed in selected woods, was continued in 1951. This completes the fourth year of the main enquiry, and it had been hoped to issue a comprehensive report. Unfortunately delays were experienced in the collection of the record cards from one area, and it has now been decided to complete the fifth year's work and then to wind up the general investigation, though retaining the watch on a few woods for a much longer period. The results for 1951 are very similar to those for previous years. Perhaps the most interesting factor brought out concerns the areas of Scots and Corsican pine in Thetford Chase, where, as in previous years, the breeding season was later (by over a week) in the Corsican than in the Scots pine. The areas in question are four miles apart, and to test the matter further, the Lynford Hall Forester Training School group had boxes erected in a marginal belt of Scots pine in the same plantation as the Corsican. It was interesting to discover that though the titmice in this belt of Scots pine were only a few hundred yards from their fellows in the Corsican pine, they nevertheless nested several days earlier. Other valuable data of a similar quantitative nature were obtained on breeding seasons, clutch size and nesting success, and will be reported fully in due course.

In all, nest record cards were submitted for 308 Great Tits, 290 Blue Tits, and 176 Coal Tits. The Forester Training School at Lynford Hall (F. Pridham, G. Flint) completed record cards for 170 nests in Thetford Chase, Norfolk; Charterhouse School Natural History Society (T. R. Garnett) completed 140 cards for Alice Holt Forest, Hants.; J. M. D. Mackenzie completed 108 cards for Perthshire; the Forester Training School in the Dean Forest, Glos. (Dr. B. Campbell, W. P. Lewis, E. Roberts) completed 101 cards; A. C. Archer completed 70 cards for Glentress Forest, Peebles-shire; for Wareham Forest (J. H. Styles) 53 cards were completed; R. Fletcher completed 23 cards for Gwydyr Forest, Caernarvonshire; P. L. F. Smith completed 21 cards in Ockley, Surrey, and Benmore Forest Training School in Argyll completed 6 cards. In addition records of 82 nests were obtained by the Edward Grey Institute (J. A. Gibb, I. Dost) in Wytham Wood, Oxford.

These nest-box investigations were started firstly to determine whether the erection of nest-boxes increased the population density of titmice nesting in managed woodlands, and secondly to determine whether these insectivorous

birds were of appreciable benefit to the forester. The first of these objects may be considered established. After nest-boxes have been set up in a wood, the population of breeding titmice gradually rises over several years and then levels off. The new and higher level round which the tit population now fluctuates must be determined by some other factor, presumably food supply. The second object, to measure the impact of titmice on the caterpillar populations of woodland, is to be studied at Thetford Chase Forest, East Anglia, by two members of the Edward Grey Institute staff, J. A. Gibb, (ornithologist) and Miss M. Betts, (entomologist), with the help of a grant from the Nature Conservancy; this work commences in April, 1952 and is to continue for five years.

STUDIES ON THE RELATIONSHIP BETWEEN LARCH CANKER AND TRICHOSCYPHELLA WILLKOMMII

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

The object of these investigations is to determine the relative importance of the larch canker fungus, frost and other agents as factors involved in the initiation and persistence of cankers on larch. The taxonomy of the fungi associated with larch canker is confused, and this was studied before approaching the main problem.

Taxonomy of the Fungi Associated with Larch Canker

A number of collections from both cankers and dead twigs of European larch and Japanese larch were made. These were examined in detail and compared with exsiccati from the Kew, Stockholm and Geneva Herbaria. The results obtained confirm, in general, those of Hahn & Ayers (1934) in that two species can be clearly defined, one, usually known as *Dasyscypha calycina*, saprophytic on dead twigs and bark, the other, usually called *D. willkommii*, apparently parasitic on cankers. The valid name for *D. Willkommii* is *Trichoscyphella willkommii* (Hartig) Nannf., (see Nannfeldt, 1932). As pointed out by Dennis (1949), the name *Dasyscypha calycina* cannot be used for the saprophytic species on larch, and no acceptable name is at present available for this species, which will be described as *Trichoscyphella hahniana* (Seaver) n. comb. in a forthcoming paper. The two species on larch can be separated in the field by an experienced observer. They are also separable on morphological characters, such as ascus and ascospore length and the nature of the paraphyses, and on cultural characters.

Inoculation Experiments

The object of these experiments has been to determine whether *T. willkommii* and/or *T. hahniana* can cause cankers either with or without the intervention of frost, and to study the factors involved in the persistence of any cankers produced. These matters have been the subject of much controversy (Day, 1931; Hahn & Ayers, 1943). A number of trees of European larch, 3 to 6 years old, in a nursery in a frost-free locality near Penzance were kindly made available by

Mr. T. R. Peace, the Forestry Commission pathologist. Trees were inoculated in 1950, 1951 and 1952, and results so far obtained indicate that, of 32 trees inoculated with *T. willkommii*, 22 (70%) became infected, and of 22 trees inoculated with *T. hahniana*, 3 (12.5%) became infected. Several single spore cultures of each species were used for inoculation, and the three infected by *T. hahniana* were all inoculated with a culture in certain respects intermediate between the two species. The infections obtained consisted of small cankers, not very resinous, surrounded by small apothecia. These cankers are being kept under observation to determine the time for which they will persist in the absence of frost. No difference in pathogenicity between cultures from European larch and those from Japanese larch was observed.

Preliminary experiments have been made, involving the freezing of small potted trees of European larch in order to obtain frost damage. The trees are being grown in specially built cold frames so that fortuitous frost damage cannot occur. Damaged and undamaged trees have been inoculated with *T. willkommii*, and there are some indications that cankers are more severe on damaged than on undamaged trees.

Future Work

The trees inoculated at Penzance will be examined at intervals to determine the extent to which cankers can persist in the absence of frost. Further experiments will be carried out involving the inoculation of trees damaged locally by mechanical means or by low temperatures, and the effect of further damage, e.g. at yearly intervals, on the persistence of any cankers produced, will be studied. The fungus *Erinella pommeranica*, which is externally similar to *Trichoscyphella*, and which is associated with small cankers on Scots pine in the New Forest, will be investigated.

References

Day, W. R. (1931). *Forestry* 5, 41-56.

Dennis, R. W. G. (1949). *Mycol. Pap. Commonw. Mycol. Inst.* 32, 97pp.

Hahn, G. G. & Ayers, T. T. (1934). *Mycologia* 26, 73-100.
(1943). *J. Forestry* 41, 483-495.

Nannfeldt, J. A. *Studien über die Morphologie und Systematik der nicht—Lichenisierten Inoperculaten Discomyceten.* 1932.

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