FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDED MARCH, 1959

LONDON

HER MAJESTY'S STATIONERY OFFICE

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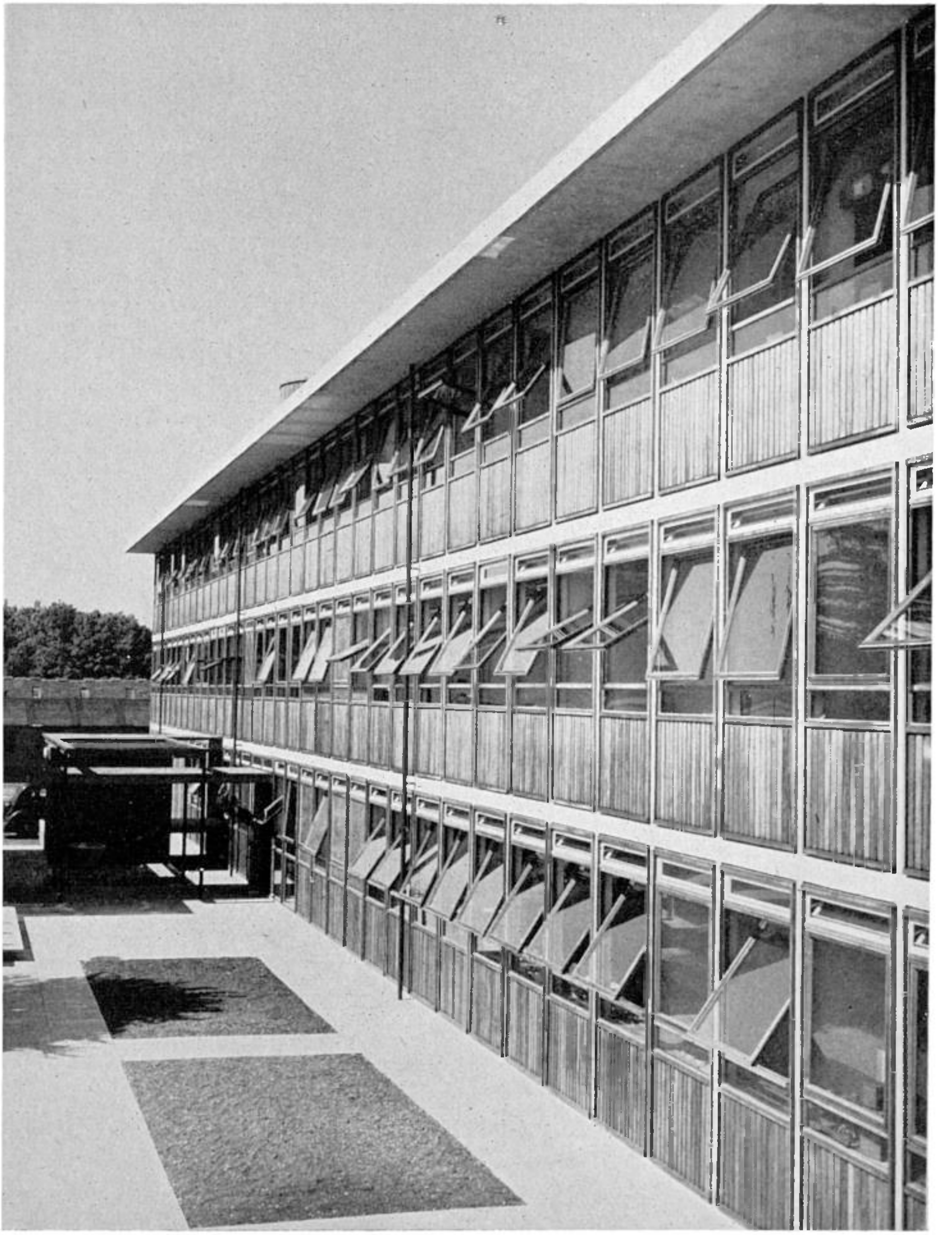

Frontispiece: The New Wing at Alice Holt Research Station.

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CONTENTS

PART I

REPORTS OF WORK CARRIED OUT BY FORESTRY COMMISSION RESEARCH STAFF

PART II

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

PART III

RESULTS OF INDIVIDUAL INVESTIGATIONS

APPENDICES

INTRODUCTION

By JAMES MACDONALD

Director, Research and Education

Mr. M. V. Laurie, who has been Chief Research Officer since 1946, has been chosen to succeed Sir Harry Champion when the latter retires from the Professorship of Forestry in the University of Oxford. Mr. Laurie will take up his new appointment on October 1st, 1959, and he will be succeeded as Chief Research Officer by Mr. T. R. Peace, who has been head of the section of Pathology for some time. During his service as Chief Research Officer, Mr. Laurie has played a very important part in the development of forest research in this country, and all who have had the pleasure of working with him, wish him well in the important post to which he has been elected.

Accommodation at Alice Holt became inadequate for the needs of the Research Station some years ago, and as a temporary measure a number of huts were erected from time to time to house the overflow. The particular need was for properly designed and equipped laboratories, and proposals for an additional building providing these facilities have been under consideration for a number of years. Plans and estimates were approved in the Autumn of 1956 and work on the site commenced in December of that year.

The building, which is shown in the frontispiece, consists of a three-storeyed main block, 195 feet long and 36 feet wide, connected to the northern end of the old Lodge by a link containing a staircase and giving through access at ground and first floor levels. The construction consists of a reinforced concrete framework on concrete piles sunk 36 feet into the clay. The corridor is off-centre, giving 12-foot deep rooms on the western side suitable for individual offices and personal laboratories, and 16-foot deep rooms on the eastern side suitable for the larger laboratories.

The cladding of the building consists of prefabricated panels of African mahogany (*Khaya* spp.) carrying full-width windows pivoted at the centre. Inside the panels is continuous ducting along which pass the water, gas, drainage and telephone services. Laboratory benches and other fixtures are of iroko (*Chlorophora excelsa*), and the doors are of beech.

The total floor area in the main block is 20,475 square feet, and it houses the following sections:

Top floor —Silviculture, Ecology and Soils Sections, with their laboratories.

First floor —Pathology section and laboratory with culture chamber, culture store, sterilising room etc., and seed testing laboratories with cold chamber. Genetics section with its laboratory.

Ground floor—Entomology section, with laboratory and space for controlled environment chambers, to be fitted out later. Photographic section with well equipped dark-rooms, a large studio and a long room for the photograph and slide collections.

The Forestry Commission Central Seed Store, with three large refrigerated chambers capable of storing up to 42,500 lb. of seed in sealed containers, seed processing room, where seed can be dried, mixed, cleaned, etc., and space for receiving, weighing, packing and despatching seed in large quantities. The advantage of having the seed store located in the same building as the research station is that technical supervision of the conditions of storage, and the testing of all lots of seed in the seed testing laboratories, can be done by the staff of the seed section.

In addition to the main wing there is a single-storeyed service block containing the oil-fired boiler for central heating, workshops, electricity sub-station, soils grinding room, poison store and general store. A staff restaurant has also been provided.

The seed store was the first part to be occupied (September 1958) and by the end of March, most of the other sections had moved into their new quarters, though various items of work still remained to be completed.

The old Lodge is now undergoing minor alterations and redecorations and will house the Library (to be considerably enlarged), the Management section, the Statistical section, the administrative offices, and the Conference room.

Dr. F. C. Hummel, head of the Management Section, left for Rome towards the end of March 1959, his services having been lent to F.A.O. for a special assignment for a period of approximately six months. Mr. R. S. Howell has been appointed Scientific Officer and has been posted to Edinburgh where he will act as Statistician. In pursuance of the policy of increasing research into the biology of squirrels with a view to obtaining better control of these animals, an appointment has been made of a Scientific Officer, Mr. K. D. Taylor. Mr. Taylor has been stationed, to begin with, at the Infestation Control Division of the Ministry of Agriculture at Tolworth, Surrey, as the Commission's work on squirrels is closely linked with that of the Ministry.

Due, in some measure, to the dislocation caused by building operations, visitors to Alice Holt were fewer than in recent years. They numbered 316 and included representatives from the following countries: Argentine, Australia, Brazil, Canada, Ceylon, Ghana, India, Iran, Ireland, Japan, Kenya, Malaya, the Netherlands, Poland, Rhodesia, Sarawak, South Africa, Sudan, Sweden, Tanganyika, Turkey, Uganda and the United States of America. Among them were Mr. Erskine Childers, Minister of Lands, Dublin, and Mr. D. R. de Wet, Director of Forestry in the Union of South Africa. Students from the Imperial Forestry Institute, Oxford, and from the Universities of Edinburgh, Aberdeen and Wales, paid their annual visits to the station at Alice Holt, while among other parties were Regional Officers of Nature Conservancy, Head Foresters of the Grosvenor Estates, members of the Gloucestershire Branch of the Royal Forestry Society of England and Wales, and students from the Royal Agricultural College, Cirencester.

Experiments in the forests were visited by the European Forestry Commission of F.A.O., who saw some of our work at Allerston in Yorkshire and the Forest of Ae, Dumfriesshire. Members of the Scottish Tree Seed Association visited experiments on larch provenance in Scotland; and forestry students from Aberdeen and Bangor, and botany students from Manchester, paid their annual visits to various experimental areas. Benmore Forest Garden was visited by a party of school teachers, the experiments at Broxa, in Yorkshire, by school children, and the Bush Nursery by members of the Edinburgh Law Society.

Experiments in various parts of the country were also examined by forest officers from Canada, Libya, Northern Ireland, Southern Rhodesia, Tasmania, Turkey and the United States.

The Director visited Ireland in May 1958 as a member of a small delegation from the Forestry Commission; he also visited Brussels, where he presided over a meeting of the Permanent Committee of the International Union of Forest Research Organizations in September. Mr. Peace visited Holland to discuss problems in plant pathology with Dutch specialists, Mr. Jobling attended a meeting of the International Poplar Commission in Rome, and Mr. Holmes visited Holland to study techniques in commercial nurseries. The Joint F.A.O./E.C.E. Committee in Forest Working Techniques and the Training of Forest Workers invited the attendance of Mr. Richards, Colonel Shaw and Mr. Jeffers at meetings in Geneva; Mr. Richards also attended a meeting of the E.C.E. Timber Committee in Geneva and a meeting, in Paris, in connexion with the E.P.A. Small Scale Pulping Project. Dr. Crooke attended the International Conference on Insect Pathology and Biological Control at Montreal, and Dr. Hummel took part, in a meeting at Koblenz, of the Arbeitsgemeinschaft für Forsteinrichtung.

Mr. Lines paid a visit to the southern and western parts of Ireland to examine plantations of lodgepole pine. The forest authorities in Dublin are considering the classification of stands of this species in respect of their suitability for seed collection, and they suggested that since we, in Great Britain, are engaged in similar work, it might be possible to arrive at a common basis of assessment. Whether this will be possible we do not yet know, but work is continuing. The Ministry of Lands in Dublin have also co-operated in the joint research which we are conducting with the Forest Products Research Laboratory, by providing samples of lodgepole pine for testing of larger sizes than we can readily obtain here. Their help is greatly appreciated.

Substantial progress has been made in investigating the properties of home-grown timber. The large programme of work which is being undertaken by the Forest Products Research Laboratory, in conjunction with the Commission, is now fairly under way, and good progress has already been made with Sitka spruce, which has been chosen as the first timber for investigation. We are greatly indebted to the Director of the Forest Products Laboratory, and his staff, for all the assistance they have given.

In May 1958, the Machinery Development Officer organised an exhibit of forest machinery which the Commissioners decided to hold at Bramshill Forest. This exhibition, which was a great success, lasted for two days and was attended by about 3,000 visitors.

The Advisory Committee on Forest Research met at Windermere in October 1958, and its sub-Committee, on Nursery Nutrition, at Aberdeen in January 1959. The Advisory Committee on the Utilization of Home-grown timber, the Committee of Management of the National Pinetum at Bedgebury, and the Advisory Committee on Westonbirt Arboretum, each held two meetings during the year.

During the year, close contacts have been maintained with the Imperial Forestry Institution, Oxford, with Rothamsted Experimental Station, and with the Macaulay Institution for Soil Research at Aberdeen. All three institutes have given valuable help to the Commission.

SUMMARY OF THE YEAR'S WORK

By M. V. LAURIE

Chief Research Officer

The Season

In England and Wales, 1958 was a wet and dull year and the combined rainfall for May and June was the heaviest since 1819. In Scotland rainfall was below normal—the summer was excessively wet in the east, but less wet in the west. The winter was unusually foggy. Sunshine in Scotland was a little above average, but in England and Wales was below average in every month of the year except January.

During the spring, rainfall was generally well distributed except for early April, when a period of drying easterly winds caused considerable damage to many newly planted trees both in forests and nurseries. In most nurseries, however, conditions during the germination period were better than average.

Easter was the coldest ever recorded, and snow fell in many places both in Scotland and Northern England. Fortunately damaging spring frosts were very few in the south, except for one or two during the first half of April; but there were several in Scotland during May.

July and August were extremely wet over most of England and Wales but both these months and also November were unusually dry in Scotland.

During the summer months gales were more frequent than usual but few were severe; one of the worst occurred in south-west England on June 25th, with gusts up to 64 m.p.h.

On September 5th a tornado moved in a narrow track across parts of Sussex, Kent and Essex and, judging by the damage done, the wind must have reached hurricane force. In places the storm was accompanied by hail stones over 2 inches in diameter, together with torrential rain; and tree trunks over 4 feet in diameter were twisted and broken.

January 1959 was exceptionally cold but very sunny in Edinburgh, the sunniest since their records began in 1891, while at Kew, except for 1952, it was the sunniest since 1881. On January 6th gross minimum temperatures fell to —5° Fah. in parts of Scotland, and frost penetrated the ground very deeply. Around January 15th there was another very cold spell in both England and Scotland.

Over the whole British Isles February was one of the driest ever recorded, with only 14% of the normal rainfall in England and Wales and 43% in Scotland. March, on the other hand, was wetter than usual over most of the country though, strange to say, Edinburgh had the lowest fall for this month since 1929. It was a mild month and there were practically no severe frosts.

In general the year was favourable to tree growth and the spring was good for nursery work.

Attacks of aphis on a number of species were unusually numerous in Scotland.

PART I

This part deals with current experiments and investigations carried out by the Research Branch of the Forestry Commission. Only the more important results are mentioned in this summary.

Forest Tree Seed Investigations

BEECH SEED STORAGE. It is found that beech seed can be dried down to 9% moisture content without damage, and that viability was maintained at a satisfactory level for 22 months at a temperature of +2°C. in a dried current of air. Refrigerated storage in sealed containers at 20 to 25% moisture and a temperature of —10°C. still gave good germination (70 to 90%) after 21 months. The tests are continuing.

Nursery Investigations

In the series of investigations of techniques for raising seedlings of various species of silver fir, this year's results contradicted last year's in many cases. More work is necessary to elucidate the conditions under which seed stratification or prechilling, and early or late sowing, are beneficial or harmful.

In the long-term fertility demonstrations with contrasted organic and inorganic regimes of manuring, it was found that, after up to nine years' continuous manuring and cropping with Sitka spruce seedlings, treatments containing either hopwaste or a hopwaste-bracken compost maintained a higher level of fertility than those using inorganic fertilizers alone.

Late and heavy applications of nitrogen fertilizers were shown to delay the formation of the terminal buds of seedlings by two to three weeks in some cases. No increased susceptibility to autumn frost damage has however yet been demonstrated.

In transplant lines, early spring applications of an N.P.K. fertilizer, (early March) were found to be damaging. Little or no damage was done by mid-April dressings up to 8 cwt. per acre. Corsican pine and Norway spruce were more susceptible than Scots pine.

In an experimental "Dunemann" seedbed at Kennington nursery, although yields were high and growth good, they were no better than on conventional seedbeds in other parts of the nursery. The species tested were Sitka spruce, Japanese larch and western hemlock.

The effect of covering seedbeds of Japanese larch and Douglas fir with polythene sheet, from the date of sowing until four weeks after seedling emergence, was to increase height growth at the end of the season by about 20%. No increase in the number of seedlings per square yard was obtained.

In spite of the wet summer from July onwards, irrigation of seedbeds in times of water deficiency resulted in significantly greater height growth in eight out of nine species sown. Germination was more rapid and yields of seedlings higher in the case of *Tsuga heterophylla* and *Abies nobilis*. Other species were not affected.

A number of fungicidal seed dressings were tested to see whether they had any effect on germination in nursery beds, but no consistent benefits were shown. It is clear that the large difference between the number of viable seeds sown and the number of seedlings that emerge is not due in any appreciable measure to seed-borne fungi. In an attempt to control soil fungi that cause damping off by a "thiram" drench, many seedlings were killed by the latter, and the surviving seedlings were smaller.

The insecticide "dieldrin", has sometimes been observed to act as a bird repellent, but trials of dieldrin sprays on nursery beds showed it to be quite ineffective in practice.

Hand weeding trials in seedbeds again demonstrated the costliness of infrequent weeding, inasmuch as weeding at eight-week intervals involved over twice as much total weeding time as weeding at two or four week intervals.

A number of chemical weed killers were "screened" for their effects on weeds and on conifer seedlings and transplants; but none of them approached the currently used vaporising oil or white spirit in efficiency or low cost. Tests of weed-suppressing mulches of black polythene sheeting, sisalkraft paper and foil, as used in the horticultural industry, were unpromising. They are unlikely to have a future in forest nursery practice in view of the difficulty of handling and of the poor weed suppression achieved. Good control of weeds in newly-planted poplar plantations was obtained with a single application of 4 lb. of "monuron" in 100 gallons of water per acre, without any damage to the poplars.

Silvicultural Investigations in the Forest:

South and Central England and Wales

AFFORESTATION PROBLEMS—In ploughing experiments on five problem sites, in which different intensities of cultivation were compared, it was found after three years from planting that complete ploughing was superior to the usual single furrow ploughing, giving better growth, a more widespread root system, and a longer period before re-invasion by heather and other competitive weeds. The long-term benefits remain to be assessed.

On the Lizard Peninsula of Cornwall, the Monterey pine, *Pinus radiata*, is the most promising species, but the difficulty of securing good survival after planting has been a drawback. In this connection, September and October planting gave better results than spring planting.

IMPROVEMENT OF CHECKED PLANTATIONS—Manurial experiments on a number of checked areas on infertile sites have continued, and confirm that, in nearly all cases, phosphate dressings provide the remedy. In some cases, heavy dressings of 6 oz. per plant or more are necessary to produce a prolonged growth response. In heather infested areas, spruces suffer from nitrogen deficiency, and dressings of 'Nitrochalk', at 45 to 225 lb. per acre, produced temporary responses lasting one to two years. A search is being made for more persistent forms of nitrogen fertilizers. Aerial application of fertilizers to checked crops, using fixed-wing aircraft, has been done successfully on an experimental scale at a cost of about £1 per acre for the actual spreading, or £6 per acre inclusive.

NUTRITION OF POLE STAGE CROPS—A second series of experiments was laid down in spruce crops in 8 localities, testing for growth responses to N, P, K, Ca and Mg. (Last year's series was on Scots pine crops). It is too early to report any results.

WEED CONTROL—For complete herbage control on ground where tractor-drawn equipment cannot be utilised, the present recommended treatment is application of 2,4-D/2,4,5-T at 3 lb. (acid) plus 'dalapon' at 7 lb. acid per acre for initial control, followed by maintenance treatments with 'Simazin' at 8-10 lb. per acre. Various other new herbicides are also being tested. For grass control Dalapon at 10 lb. per acre has given good results, but it is highly selective and does not discourage broadleaved weeds. Trials are in progress to test the resistance of planted trees to these chemicals.

CONTROL OF WOODY GROWTH—Practical scale applications of 2,4-D and 2,4,5-T for controlling woody and herbaceous growth in preparing land for planting have been carried out in five Conservancies, with a view to determining the silvicultural value and costs of these techniques. Foliage spraying or treatment of freshly cut stumps have been effective, but basal bark spraying has been disappointing. In stump treatment the edges and bark are the most vulnerable parts, and it is found to be a waste of material to spray the whole of the cut surface.

Control of heather prior to planting with 2,4-D ester at 5 lb. (acid) in 50 gallons of water per acre has been highly effective, but if done after planting damage may be done to the tree crop unless carefully directed sprays are used. The response of trees to fertilizer applications is greatly enhanced after killing the heather.

Dwarf gorse was effectively controlled with 2,4,5-T ester at 3-4 lb. (acid) per acre as an overall spray in May-July.

For rhododendron control, the only fully effective treatment is by application of ammonium sulphamate to the cut stumps.

GIBBERELLIC ACID—Preliminary experiments were extended, but only confirmed that conifers showed little or no growth response to this stimulant. The only results were a large response in beech, and a somewhat smaller response in *Nothofagus*. 1% gibberellic acid in lanolin applied as a smear to a two-inch length of the leading shoot was the most effective method of application. Poplar cuttings showed no responses.

FIRE RETARDANTS—Tests continued with both sodium calcium borate and mono-ammonium phosphate. Both showed promise of being of some tactical value in fire fighting.

CHEMICAL METHODS OF PRUNING—Preliminary tests of spraying unwanted side branches with amyl. 2,4,5-T gave promising results with poplars, but less so with epicormic branches of oak. If successful, it will result in a great saving in manpower for pruning.

Silvicultural Investigations in the Forest:

Scotland and Northern England

REPLANTING AREAS OF RECENTLY CLEARED CONIFERS—Four more experiments have been laid down, bringing the total to nine. One early conclusion is apparent, namely that in order to cope with the rapid and vigorous invasion of grasses in such areas, it is necessary to use much larger plants than is usual on fresh afforestation ground.

AFFORESTATION PROBLEMS—New experiments have been established on peat sites in the Border country to find the best alternative species to Sitka spruce. Large blocks of lodgepole pine have also been established in areas normally considered too poor to plant, for future experimentation. Some further plots were established in the Pennines to study the effects of atmospheric pollution on tree growth.

MANURING IN THE FOREST—An experiment in the series of pole-stage manuring trials was laid out in Scotland in Quality Class III Norway spruce. The usefulness of foliar analysis to diagnose deficiencies, and to predict the likelihood of response to particular fertilizers, is being studied in collaboration with the Macaulay Institute.

PRUNING—Analysis of trees blown down in the Inverliever pruning experiments started 19 years ago in Norway and Sitka spruce crops showed no ill effects from the pruning of live branches, and illustrated again the smallness of the layer of knot-free timber laid on during that period. This emphasized the necessity to prune only the largest, most vigorous trees in a crop, and to start pruning when their diameter at breast height was about 4 inches, i.e. at an earlier date than brashing is usually done.

PROTECTION AGAINST DEER—Experiments were started to see whether effective protection of young plants against deer could be obtained more cheaply than by fencing. The laying of branches on the ground afforded some protection. Trials are now being made with old sheep netting supported horizontally on six-inch pegs, and with electric fencing.

Provenance Studies

Surveys of existing stands of various strains of *Pinus nigra* suggest that the provenance factor is worth investigating with respect to elevation and atmospheric pollution. Seed from plantations of the third generation in Belgium and France may prove of interest in this connection.

A visit has been paid to the Irish Republic to study the older plantations of lodgepole pine with a view to selecting stands suitable for seed collection. Provenance experiments recently established have aimed mainly at finding our best source of seed of the coastal form of this species.

An interesting provenance collection of Japanese larch has been obtained through the kindness of Dr. Langner of Schmalenbeck, Germany, and Professor Iwakawa of Japan. Considerable differences in growth rates and phenological habits have appeared in the nursery.

In Sitka spruce, we have for the first time a reasonably comprehensive collection of provenances from the latitudinal range of the species. Far northern provenances (from Alaska) have grown slowly in the nursery and hardened off early. Southern forms (from Oregon) tend to grow on late into the autumn.

Little being known about the provenance attributes of western hemlock (a species which is gaining in importance in Britain), a collection of seed from sixteen origins widely dispersed over its natural range has been sown in the nursery.

A collection of provenances of Douglas fir, planted in 1954 on an especially frosty site in Norfolk, has yielded some useful information on varietal differences in frost susceptibility. Provenances from sites close to the Washington coast appear markedly less frost susceptible than those from further inland. Little relationship has appeared between height growth and frost susceptibility.

Poplars

The varietal trials continue to give interesting results. At the most favourable sites the most vigorous varieties have reached 50 feet in height (62 ft. maximum) in 8½ years, with girths of about 26 inches (29.5 in. maximum) at breast height, and standing volumes of about 750 hoppus feet per acre—(18 foot × 18 foot spacing). Unfortunately the most vigorous variety "Androscoggin" has been found to be susceptible to bacterial canker. Experiments on the best age and type of planting stock confirm that two-year rooted sets are much more satisfactory than one-year rooted sets, which in turn give better results than unrooted sets. Planting in holes made by explosives gave better growth after four years, than in holes made by a post-hole borer or in hand-dug pits, the latter two being equally good. Mulching with cut vegetation or straw was found to give better growth than with bark peelings or used fertilizer bags. Spacing experiments have been started, using close spacings (down to 7 ft. × 7 ft.), of a narrow-crowned variety to determine the optimum spacing and rotation for pulpwood production.

Elms

An intensive study has been started of the varieties of elm in Britain with a view to finding those which have the timber properties most favoured in the furniture trade, and have at the same time good silvicultural characteristics.

Forest Ecology

Work has again been concentrated on the study of Corsican pine, to determine the limits of elevation and climate within which it can be safely grown. A visit was paid to Corsica to collect data on the conditions under which the trees that provide our seed are growing. It appears that, in Britain, low summer temperatures combined with conditions of air stagnation may be the predisposing factors for disease. There is no evidence that exposure to winds is detrimental to the health of Corsican pine.

Forest Soils

The Soils Section has been kept busy doing soil and foliar analyses for other sections, and in particular in connection with the forest manuring trials by the Silviculturist. Sampling problems for foliar analysis are also being investigated.

Forest Genetics

Progress continues to be made with the building-up of a collection of material for breeding work. The total number of plus and special trees of all species is now 2,726; the pines, larches and Douglas firs account for two-thirds of these. More spruces are now being selected. Just over half of the plus and special trees, i.e. 1,581 of them, have been propagated vegetatively and just over one-third (1,075 clones) are now established in tree banks.

Propagation by grafting was continued at Alice Holt, Grizedale and Bush nurseries. 12,727 grafts were attempted and the overall success was 70 per cent.

The outdoor grafts, especially of larch, were spoiled by cold, dry winds soon after the work was completed, but a possible solution to this problem was seen in the successful trial use of polythene protection at Bush nursery.

The series of experiments on the rooting of cuttings of Leyland cypress (X *Cupressocyparis leylandii*) was rounded off and written up during the year. The "mist" propagation unit proved very successful for rooting summerwood cuttings of several clones of poplars and elms, and a new "mist" unit has been installed.

Inter and intra-specific hybridization work continued in the two-needled pines and Douglas fir, the pine work including crosses between several provenances of Scots pine and also the two species crosses: Corsican pine × Scots pine and Scots pine × lodgepole pine. Ninety-five larch progenies derived from the 1956 crossing programme were planted out at four sites; and fifteen Douglas fir progenies, also produced in 1956, were set out, together with several home and American provenances.

The planting of seed orchards continued, and work was done at 19 sites totalling 205 acres. The summary of the present position shows that 131 acres have been planted or are in an advanced state of formation. There are now 50 acres of Scots pine seed orchards and 49½ acres of larch seed orchards.

Techniques being studied include the effects of root pruning, stem girdling, shoot pruning and applications of nitrogen, phosphorus and potassium on the flowering of six-year-old Scots pine trees. Stem girdling, applied in May 1957, increased flowering in several eight-year-old clones of grafted beech at Alice Holt.

Forest Pathology

The needle fungus *Lophodermium pinastri* again caused losses of Scots pine stocks in nurseries in 1958, and enquiries showed that attacks were almost entirely confined to nurseries made in pinewoods. One remedy is to confine Scots pine sowings to nurseries that are not in or adjacent to Scots pine plantations. The seedling and transplant disease caused by the fungus *Ascochyta piniperda*, which has only previously been detected in this country on Norway spruce, has now been found on various species of pine.

Experimental lighting of fires in the forest has shown that fires lit at any time of year can be colonised by the fungus *Rhizina inflata* which causes group dying in conifer plantations.

In an infection bed of mixed pines and aspens, it has been found that Scots pine and *Pinus pinaster* become badly infected with the rust fungus *Melampsora pinitorqua*, but eight other species tested, including Corsican and lodgepole pines, are so far apparently immune to the disease.

The clones of Weymouth pine, selected in America as resistant to the blister rust disease and imported some years ago, still remain healthy in the test bed where they are subjected to intense infection, and where other clones have rapidly succumbed.

Further spraying trials in attempts to control *Botrytis cinerea* in conifer nursery beds have failed to achieve satisfactory control.

Fomes annosus continued to be the major project under investigation. Development of the fungus is found to be rapid in plantations on old agricultural ground, and early protection by creosoting the stumps of all felled trees is found to be particularly necessary on such sites. Hemlock was again found to be highly susceptible to decay by *Fomes*, and restrictions on the use of this species in relation to the infection of the site were advised.

Forest Entomology

Work on the pine looper moth, *Bupalus piniarius*, was continued. The annual pupal survey revealed increases in population in almost all of the forests surveyed. In general, the increases are of little immediate significance, but substantial rises in numbers have been recorded at Cannock Chase, Tunstall, Sherwood, and Rendlesham Forests. Artificial control measures may be required at the latter two localities.

A series of plots to study the quantitative effect of *Neomyzaphis* defoliation on increment in Sitka spruce crops has been set up. Studies have been commenced on two beetles—*Trypodendron lineatum* and *Hylecoetus dermestoides*—which are currently causing degrade of softwood logs in west Scotland. The distribution of the bark beetle *Ips cembrae* in the north-east of Scotland was resurveyed (see page 14). Initial work was undertaken on *Anoplonyx destructor* with a view to an intensive investigation of the ecology of this larch sawfly.

A trial was carried out with aircraft fitted with rotary atomisers for forest spraying; results were promising and further tests are proposed.

Forest Management

Work continued in the four sub-sections of this section, namely Mensuration, Census, Working Plans and Economics.

In the Mensuration Section, much time was spent in the preparation of forecasts of production and testing new techniques for Working Plan surveys. Yield tables for *Abies grandis* and *Abies nobilis* have been prepared, and tables giving the growth of poplar under various assumed treatments were compiled.

Work in the Census Section was reduced. Future Census of Woodlands work will be based on sample surveys, which will give sufficiently accurate estimates of the overall position by countries, but not for areas as small as individual counties.

The Working Plans Section participated in the drafting of the new departmental Working Plans Code. Over 100,000 acres have been surveyed for working plan purposes by the Management Section field staff, and procedures for crop assessment and forest inventory tested and put into operation.

The Forest Economist has made some studies of the economics of growing hardwoods, which included studies of hardwood markets in this country. The results emphasize the susceptibility of the demand for hardwoods to price changes, and the heavy financial burdens involved in planting hardwoods. Other studies included (a) One on the best way of expressing profitability in forestry, (b) Costing of seedling production in nurseries, and (c) Costing of sawmilling costs per cubic foot of out-turn in relation to the size of logs supplied to the mill.

Design and Analysis of Experiments

The main work of the Statistics Section has been in the continuation of the advisory service, on the design and analysis of experiments and surveys, to other sections of the Research Branch and to the Forestry Commission generally. A recent development work has been the transfer of virtually all computing from electric desk calculating machines to an electronic digital computer, the Ferranti "Pegasus" computer, used by courtesy of the Royal Aircraft Establishment at Farnborough. As a result, the Section is better able to cope with the rapidly increasing weight of computing being placed upon it.

In addition to the advisory and service work, investigations into the application of statistical methods to problems of forest research and management have continued. They have included the applications of multivariate analysis, methods of analysing perennial crop data, and the use of growth curves describing the development of tree growth.

Utilisation Development

The destructive testing of home-grown pit props at the Forest Products Research Laboratory and the investigation into the use of timber in building were continued. A survey of the yields of hardwood coppice was completed for ten species. Poplar and willow gave the highest rates of production, followed by sweet chestnut. An extensive investigation was started in collaboration with the Forest Products Research Laboratory into the properties of home-grown Sitka spruce in relation to silvicultural treatment and site factors.

Machinery Research

The activities of the Machinery Research Section were dominated by the Forest Machinery Exhibition at Bramshill Forest in May, 1958.

New development work has been directed towards:

(a) Modifications to improve the cross-country capacity of wheeled vehicles.
(b) Research into the long-standing problem of cleaning forest drains.
(c) The development of a portable conversion plant based on the line system.

Trials of proprietary machines continue to be carried out for the information of both users and manufacturers.

PART II

This part consists of reports of progress made by workers attached to Universities and other institutions. The subjects covered are usually of a more fundamental nature and much of the work is assisted by grants from the Forestry Commission.

Mycorrhiza and Soil Mycology

Referred to in previous reports as "Researches on Mycorrhiza", Dr. Levisohn's work at Bedford College, University of London, has been extended to cover the action in the soil of a range of fungi, some of them potential mycorrhiza formers but others not known to form mycorrhizas. The studies include not only the effects of these fungi on tree growth whether or not root associations are actually formed, but also their action on one another.

The way in which soil sterilization in agricultural type nursery soils acts to stimulate the growth of conifer seedlings is still a mystery. Cytological examination of healthy seedlings raised on sterilized soil has shown that no mycorrhiza is formed even two years after sowing. On the other hand an intercellular haustorial infection has been found that does not appear to harm the seedlings. The nature of this fungus is being examined.

Investigations into the antibiotic activity of the common soil fungus *Alternaria tenuis* have been continued. It was found to inhibit the growth of several timber decay fungi, namely *Armillaria mellea, Fomes annosus, Pleurotus ostreatus* and *Polyporus betulinus* under "in vitro" laboratory conditions, though it is doubtful whether these effects will be repeatable in natural soil. It has also been found to inhibit the growth of a number of mycorrhiza formers, but to have no effect on a number of "pseudo-mycorrhizal" fungi and other parasitic root associates such as *Verticillium* and *Pythium.*

A basidiomycete, *Tricholoma albobrunneum,* frequent in good stands of pines in various parts of England, showed, in experiments carried out in soil pits, a stimulating effect on the growth of pine seedlings, and will be tested in nursery experiments as a source of mycorrhizal inoculation.

In studying the activities of mycorrhizal and other root-fungi, the new methods already mentioned in an earlier report (1957), have been successfully employed in differentiating between certain ecological groups of mycelia. In a number of cases these tests have served as a useful means of sorting out fungi of high and low rhizosphere activity, and have also demonstrated strain variations in a mycorrhizal fungal species which had been found to have unequal effects on tree growth.

Soil Mycology

At the University College of North Wales, Bangor, work has continued on this subject under the direction of Dr. C. G. Dobbs. The monthly germination assay of twelve forest soils has continued to show a seasonal variation in mycostasis, which is at a maximum in the summer and a minimum in the winter; but with a less marked contrast during the wet summer and milder winter of 1958-59 than in the previous year. A comparison with local weather records has shown some correspondence between the monthly ground-frost records and stimulated germination and growth of fungi on some of the soils.

Sugar estimations, by Dr. D. A. Griffiths, of soil samples kept at a range of temperatures, have shown that both freezing and high temperatures release reducing sugars in the soil, as well as removing any inhibitory effect. The restoration of mycostasis in chrome-washed sterile sand was found to follow infection by bacteria; and of these bacteria, three isolates which inhibited germination of test spores, all proved to be gram-negative rods.

Soil Fauna Research

Mr. D. R. Gifford, working at the Forestry Department, University of Edinburgh, reports that the ecological survey comparing unplanted *Molinia* moorland with a thirty-year-old Sitka spruce plantation was continued. It will finish in December, 1959. A study of the aggregations of Oribatid mites was begun by investigating the effect of fungal mycelium in litter upon their distribution. A technique for the sterilization of cores of litter, their inoculation with specific mycelia, and their return to the forest for a recolonisation study, was evolved.

Forest Soil Research in Scotland

Dr. T. W. Wright, working at the Macaulay Institute for Soil Research, Aberdeen, reports on the various projects under investigation.

At Culbin Forest, the small height response to phosphate applied in 1954 has been maintained, and needle phosphate contents were higher in these plots for the first time. The highly significant increase in height growth due to nitrogen applied in 1956 was maintained, and was greater in the presence of magnesium.

Mr. Binns' work at the Lon Mor, Inchnacardoch Forest, on the effects of afforestation on deep peat, has been completed, and the results submitted as a thesis to the University of Aberdeen. Tree growth has dried out the peat considerably, and there has been appreciable resultant shrinkage. Lodgepole pine fertilized with ground mineral phosphate has removed significant amounts of potassium and inorganic phosphorus from the upper peat layers, and foliage analysis suggests that the decreasing rate of diameter growth for lodgepole and Scots pine is due to exhaustion of applied phosphate; it also indicates incipient potassium deficiency in lodgepole pine.

At Wauchope Forest, where plough ridge size has had a marked effect on early height growth, monthly peat samples showed higher ammonia nitrogen and moisture contents in deep ridges. Foliage analysis of lodgepole pine and Sitka spruce showed higher needle nitrogen contents in deep ridge trees.

Foliage analysis of samples from Forestry Commission fertilizer experiments suggest that it is possible to establish ranges of the major nutrients over which growth is satisfactory, and below which deficiencies exist.

Foliage analysis of Sitka spruce from an N.K.Mg. experiment at the Lon Mor has shown an acute potassium deficiency, but only a small response to nitrogen. In a similar lodgepole pine experiment the nitrogen treatment has apparently reduced the needle phosphorus, calcium and magnesium contents; but the potassium treatment has increased needle potassium. An experiment testing ammonia, granite dust, calcium cyanamide and limestone has shown no significant effects, possibly due to an overall phosphate deficiency.

Substances in Leaves Affecting the Decomposition of Litter

Dr. C. W. Love, working at the Dyson Perrins Laboratory, Oxford, under the supervision of Dr. B. R. Brown, is trying to determine the nature of the substances in leaves that seem to hinder the decomposition of forest litter. Working with an aqueous extract of heather, *Calluna vulgaris* leaves, a number of substances have been identified which may be derived from tannins that could render leaf proteins insoluble and give rise to raw humus.

Physiology of Flowering of Forest Trees

Dr. P. F. Wareing and K. A. Longman, working respectively in the University College of Wales, Aberystwyth, and in Manchester University, have found that in Scots pine and birch, long-day conditions increase the production of both male and female flowers. In beech and Japanese larch, no effects of day length on flowering were detected, while in lodgepole pine short-day conditions appeared slightly to stimulate flower production. By manipulating day length and temperature, great increase in growth can be obtained, e.g. 5 feet in one season on beech grafts and 17 feet in two seasons for seedling birch.

Branch girdling on birch produced heavy flowering, but partial breaking of the branches did not stimulate flower production.

In experiments to test effects of N, P, and K fertilizers on cone production in Scots pine, potassium manuring increased both the number of cones and the proportion of trees coning.

Larch Canker

Dr. J. G. Manners, in the Botany Department, Southampton University, has continued his researches on the larch canker fungus, *Trychoscyphella willkommii.* Freezing of trees with dormant cankers caused the cankers to become active and to enlarge, this being associated with renewed fungal activity. Spore trapping investigations have been started to determine the conditions under which the ascospores of the fungus are liberated, and a taxonomic key to a number of species of *Trichoscyphelloidiae* from Europe and North America has been prepared.

Fomes annosus

Dr. J. Rishbeth at the Botany School, Cambridge University, has continued his work on the chemical treatment of pine stumps to prevent infection from airborne spores of this species, which occur everywhere throughout Britain, and can even be detected over 200 miles from source. Particular attention is being paid to chemicals which favour colonisation of the treated stumps with saprophytic fungi which help to suppress *Fomes* infection.

Mr. G. W. Wallis, working with Dr. Rishbeth, has made a survey of *Fomes annosus* attacks in East Anglian pine plantations, and found that soil reaction was of critical importance in determining the damage caused by the fungus. The critical value in the main rooting zone of the trees was pH 6; higher values resulted in greater damage.

Shelterbelt Research

The work at the Forestry Department, Edinburgh University, has been taken over by Mr. R. Baltaxe. The long-term investigation of the most suitable silvicultural practices for the establishment and rehabilitation of local shelterbelts is being continued. An investigation of the variation of shelter in terms of wind abatement, due to seasonal changes and different stocking densities, is being undertaken, with the object of arriving at a more detailed classification of shelterbelt permeability. A preliminary study of the effect of different kinds of agricultural land surfaces on wind speed is being made. Instruments, including a device for the remote control of cup-anemometers, a wind direction recorder and a hot-wire anemometer, are being constructed.

Tannin Content of Conifer Bark

Dr. D. E. Hathway of the Leather Manufacturers Research Association has shown that there is no appreciable variation in the tannin content of Sitka spruce stembark harvested at different seasons of the year, but that the red colour is greater in winter-harvested bark than in bark peeled during active growth periods. It was found that available tannin diminished on standing, which suggested that bark should be peeled and dried within a month of felling. In Douglas fir, higher values for tannin, benzene soluble wax and dihydroquercetin were obtained from dominant trees than from suppressed trees.

PART III

In this section, the results of certain investigations carried out by the Forestry Commission Research Branch are reported in the form of short articles. The main points of interest are summarised below.

Effects of Different Forms and Amounts of Phosphate on the Growth of Japanese Larch

M. V. Edwards reports the results of an experiment laid down in 1937, to the design of the late E. M. Crowther, comparing four forms of phosphate fertilizer, namely (1) High-grade high-soluble basic slag, (2) High-grade medium-soluble basic slag, (3) Low-grade high-soluble basic slag and (4) mineral phosphate, each applied at three levels (namely 1 oz., 2 oz., and 4 oz. per plant) at the time of planting Japanese larch plants on blanket bog at Glen Righ Forest in Inverness-shire. Unmanured controls were included. The main results were that, though the different forms gave slightly different growth responses for equivalent amounts of fertilizer (low-grade high-soluble being the least efficient in this respect), the major growth effects corresponded with the total amount of fertilizer applied per plant, regardless of the form in which it was given. The unmanured controls grew slowly, (6.2 feet in 13 years), while the average heights for the 1, 2 and 4 oz. levels were 14.1, 16.5 and 19.0 feet respectively at the same age.

Nursery Manuring

R. Faulkner reports in two separate articles on the results of a long series of experiments in Scottish nurseries on the manuring of seedbeds with (a) fertilizers containing phosphate and potash, and (b) nitrogen fertilizers. The experiments cover rates and times of application and the different forms of fertilizers used. The main results are that, with P and K fertilizers there is no danger in applying fertilizer on the day of sowing, provided it is well mixed in with the soil. Equally good results are obtained if applied earlier, up to 16 weeks before sowing. The currently recommended rate of 14 lb. of superphosphate per 100 sq. yards of nursery bed is satisfactory for Japanese larch, western hemlock and Douglas fir seedbeds, but for Sitka spruce one-and-a-half to two times this amount is recommended as giving worthwhile growth increases. For all four species, applications of sulphate of potash at the rate of 4 to 5 lb. per 100 sq. yards is generally adequate.

Nitrogen, under the usual acid conditions of good conifer nurseries, is generally best applied in the form of "Nitrochalk". Ammonium sulphate should only be used where it is desirable to remove free lime from the soil and reduce the pH. Urea had no advantage over "Nitrochalk", and in some cases caused reductions in seedling yields. Ammonia, applied as a 0.880 solution in water, similarly had no advantages, and is more difficult to handle. The best rates of application were from 5 to 10 lb. of "Nitrochalk" per 100 sq. yards, split into two top dressings given in mid-July and mid-August. Earlier applications gave poorer growth responses. There is no evidence that late and heavy applications of nitrogen fertilizers induce any susceptibility to damage by early autumn frosts.

Handling of Poplar

The main factors causing planting losses are drought, weed competition, water-logging, infection by stem fungi, damage by vermin, severe exposure, weak planting stock and poor planting technique. The results of a series of experiments started in 1953 to see how far bad handling of polar plants contributed to losses after planting are reported by J. Jobling. The practical conclusions are that root exposure, up to 40 days in January/February, does not affect survival after planting, though it may cause some crown die-back and early reduction in growth which is, however, quite temporary. Root severance at time of lifting also has no appreciable effect on survival or rate of growth. It was found that the tolerance of poplar plants to various forms of root damage during handling is similar for different ages and types of nursery stock, and for different varieties. This knowledge, however, should not be construed as permitting deliberate or careless mis-handling of nursery stock.

Re-survey of Distribution of Ips cembrae

This bark beetle was first discovered damaging and in some cases killing larch trees in north-east Scotland in 1955, and a survey of its distribution was carried out. In 1958 a re-survey was made round the perimeter of the 1955 distribution area, and it was found 6 miles further to the south-east and 22 miles further to the north. A map of the distribution is given in Plate 5.

Studies of the Indumentum of Young Shoots of Norway Spruce

R. Lines, investigating botanical characters by which different races of Norway spruce can be recognised, shows that three main groups of provenances can be separated by the hairiness of the young shoots, those from the Baltic and northern regions being markedly hairy, those from the Alps and south-eastern Europe being markedly glabrous, and those from the Carpathian-Hercynian region being intermediate. The results in provenance plantings in this country tallied with those from material from the countries of origin. The assessments of hairiness were treated statistically, and it is found that, if 150 young shoots of a provenance are scored for hairiness, the group from which it comes can be determined.

PART I

Reports of Work carried out by Forestry Commission Research Staff

FOREST TREE SEED INVESTIGATIONS

By G. D. HOLMES and G. BUSZEWICZ

Service Work

Service Seed Testing 232.231

The programme of service testing work has increased somewhat during the last three years as illustrated by the following table:

Table 1

Service Seed Tests

Seed Testing Year	No. of Samples Received	Nos. of Tests Completed						
		Purity	Seed Size	Germination	Tetrazolium	Moisture	Cone Tests	Total
1956/57	619	376	376	895	155	189	39	2030
1957/58	594	452	452	987	95	173	33	2192
1958/59	661	531	540	1126	45	338	77	2657

As specified in the Seeds Act (1920) the seed testing year covers the period from August 1st to July 31st. It can be seen that, with the exception of tetrazolium tests, there was a general increase in all determinations. The substantial increase during the last year was largely associated with the installation of the Commission's new Central Seed Store at Alice Holt. A careful check is being maintained on the new storage conditions for the first two years, involving rather more intensive sampling of stored seed than will be done in the future. There was an increase in the number of moisture content tests, as all lots of seeds going into the store were tested before sealing.

Early in 1959 the Seed Laboratory was transferred to its new premises in the recently completed new wing at Alice Holt. The new laboratories are an immense improvement on the old in design, space, cleanliness and lighting conditions. Among the many improvements introduced, the following were the most important.

(i) The number of Copenhagen tank germinators was increased from 25 to 35, and all tanks were equipped with semi-automatic control of water supply and level.

(ii) 24 tanks were fitted with an improved type of thermostat control.
(iii) The new germination room was provided with temperature control and improved lighting, giving a uniform illumination of 125 foot candles at all germination surfaces.
(iv) Specially designed and illuminated benches were installed for seed purity determinations.
(v) A small cold room, (2°C), adjacent to the laboratory provides convenient facilities for seed storage, pretreatment and some germination tests.

Service Seed Storage 232.315.2

Processing, storage, and despatching of seed required in the Station's research programme are part of the service work of the Seed Laboratory. In the last year about 200 lb. of seed was involved, which was despatched to nursery research centres in about 5,000 measured and packeted lots.

Service work was substantially increased as a result of the opening of the new Central Store. Apart from general technical supervision of storage methods, attention has also been given to seed processing, especially dewinging, cleaning and drying. A new vertical forced draught seed drier was designed and constructed in collaboration with the National Institute of Agricultural Engineering. This machine has now been installed and on completion of calibration tests, it will be used in adjustment of the moisture levels of seed lots for long storage. Attention is now being concentrated on the design of an efficient and safe seed dewinging machine for use in the extraction plants. Laboratory tests are under way to examine the efficiency and degree of injury to seed with several types of machine.

Research Work

Research Seed Testing 232.318

The weight of service work has necessitated a reduction in the number of research items actively pursued. Improvement of techniques for greater uniformity of results of seed tests continued to be the major subject of investigation. In particular, a large programme of work on the revision of the International Seed Testing Rules was undertaken as part of the work of the Forest Seeds Committee of the International Seed Testing Association. The final report on the Committee's work, which includes proposals for substantial changes in the present rules, relating to tree species, will be discussed at a meeting of the Association in Oslo in 1959. The results of this work may have important applications in our domestic seed testing methods.

In addition, a series of purity and germination tests on five referee samples of Douglas fir and Sitka spruce, together with tetrazolium tests on a number of dormant tree seeds were completed as part of the programmes of the Forest Seeds Committee and the Biochemical Test Committee of the International Seed Testing Association.

Research in Seed Storage

Investigations of the longevity of beech seed under contrasting storage conditions was continued into a third year. The storage conditions examined include temperatures of —10°C, +2°C, and +8°C with seed moisture content controlled at levels ranging from 10 to 30% (wet weight). Unfortunately, shortage of space in the former cold room did not permit germination tests to be carried out every 3 months during storage as planned. The tests completed to the end of 1958 are summarised in Table 2 below.

Table 2

Germinative Capacity of Beech Seeds during Twenty-two Months' Storage

Storage Method	Temp. °C	M.C. %	Germination % after Months 0	5	8	12	17	18	21	22	Remarks
1. Seed *predried*, stored in an open container. Seed moisture content maintained by moistening.	+2	20	95	73	91	80		73		13	
2. Seed *predried* to fixed moisture levels and stored in sealed containers.	—10	30	92	76	64		59		15		
		25	93	76	73		75		91		
		20	95	73	52		97		71		
		15	95	59	87		63		17		
	+2	30	92	95	73		17		1		
		25	93	77	80		4		8		
		20	95	73	81		25		5		
		15	95	77	64		0		0		
	+8	30	92	88	67		9		0		
		25	93	77	79		0		3		
		20	95	76	51		0		0		
		15	95	49	1		1		0		
3. Seed *predried* to fixed moisture levels, mixed with dried peat and stored in sealed containers.	+2	29	99	85	57	48	1			0	
		23	99	77	77	71	13			4	
		18	99	85	83	60	8			1	
		15	99	90	79	18	0			0	
4. *Undried* seed placed in sealed containers, the R.H. % within the containers being controlled by H_2SO_4 solutions.	+2	28	99	84	64			0			95% Air R.H. %
		13	99	67	69			0			80% Air R.H. %
		11	99	72	77			60			60% Air R.H. %
5. *Undried* seed placed in containers through which a flow of air of controlled R.H. % was passed continuously.	+2	24	99		88	57		12		0	95% Air R.H. %
		18	99		74	79		35		4	85% Air R.H. %
		15	99		67	35		1		1	75% Air R.H. %
		9	99		66	62		90		76	45% Air R.H. %

Note: M.C. = Moisture Content. R.H. = Relative Humidity.

After 21—22 months' storage the outstanding treatments were:

No. 2—Sealed storage at —10°C at 20—25% moisture content.

No. 5—Aerated storage at +2°C at 9% moisture content.

There are several puzzling inconsistencies in the results to date, but it seems evident that the seeds can be stored satisfactorily at +2°C providing the moisture content is maintained below about 11%. From the results in treatment 2, it also seems that higher moisture levels can be satisfactory if the storage temperature is sufficiently low.

One of the most important conclusions from this trial so far is the observation that beech seed can withstand drying to levels as low as 9% without injury. This opens up new possibilities in storage if a suitable practical drying procedure can be developed. Previously, it was generally believed that the seed were incapable of withstanding drying below 17—20% without permanent damage.

Examination of the long-term storage requirements of *Abies grandis*, *A. nobilis*, *A. concolor*, Douglas fir, *Thuja plicata*, and *Chamaecyparis lawsoniana* was continued into a second year, but it is too early to draw conclusions for these tests.

NURSERY INVESTIGATIONS

By R. FAULKNER and J. R. ALDHOUS

Introduction

In 1958, experiments were continued at five nurseries in England and seven in Scotland. In England, the nurseries were at: Kennington, near Oxford; Sugar Hill research nursery, Wareham Forest, Dorset; Ampthill, Bedfordshire; Yateley, Elvetham and Lychetts, Bramshill Forest, Berkshire; and Alice Holt, Hampshire. Of these, Wareham and the Bramshill group of nurseries are on heathland soils, Kennington and Ampthill are on fairly light agricultural soils and Alice Holt nursery is on a heavy and stony soil.

In Scotland, the nurseries were at: Inchnacardoch, Inverness-shire; Tulliallan, Fife; Bush, Midlothian; Fleet, Kirkcudbright; Teindland, Morayshire; Newton, Morayshire; and Benmore, Argyll. All of these are on agricultural soils, except Teindland which is on a former woodland soil.

In addition to the work described here, experiments were carried out on behalf of the Nursery Nutrition Committee at Kennington, Wareham, and Ampthill Nurseries, and also at Bagley Wood Nursery, near Kennington, Oxford, and at Ringwood Nursery, Hampshire.

Nursery Treatment of Silver Firs, Abies Species: Stratification of Seed

232.315.3

At Kennington, investigations into ways of improving the germination and seedling yield of *Abies grandis* and *A. nobilis* were continued. For both species, seed from two years' collections, 1956 and 1957, was used. The 1956 seed was that used in the similar experiment carried out in 1957 (Faulkner and Aldhous, 1959).

Seed sown dry was compared with seed stratified for 3, 6 or 9 weeks, and with seed that had been pre-chilled. Table 3 gives the results of this experiment.

It will be seen from Table 3 that dry seed sown late gave best yields; seed stratified for the shortest period, and pre-chilled seed, also generally gave good yields. Tallest seedlings were obtained from the earliest sowings of dry seed, and from the longest periods of stratification.

Table 3

Yield of Silver Firs, Abies nobilis and A. grandis, at Kennington Nursery

Treatment	Date of Sowing	Abies nobilis				Abies grandis			
		1956 seed		1957 seed		1956 seed		1957 seed	
		No. of Seedlings per sq.yd.	Mean Ht. In.	No. of Seedlings per sq.yd.	Mean Ht. In.	No. of Seedlings per sq.yd.	Mean Ht. In.	No. of Seedlings per sq.yd.	Mean Ht. In.
Seed sown dry	Feb. 3rd	167	1.76	96	1.90	133	1.37	178	1.59
	Feb. 19th	165	1.47	135	1.94	140	1.54	252	1.34
	Mar. 10th	153	1.48	86	1.35	144	1.11	291	1.21
	Mar. 31st	254	1.56	149	1.43	242	1.35	360	1.19
	Apr. 21st	234	1.62	162	1.35	250	1.19	360	1.22
Seed stratified									
3 weeks	Apr. 1st	292	1.77	125	1.42	205	1.17	319	1.35
6 weeks	Apr. 1st	243	2.19	150	2.11	178	1.46	315	1.44
9 weeks	Apr. 1st	198	2.16	169	2.19	142	1.61	305	1.65
Seed moist pre-chilled	Mar. 31st	232	1.86	118	1.62	219	1.42	308	1.31
Standard Error±		16.5	0.095	16.5	0.095	18.7	0.066	18.7	0.066

The results obtained with dry-sown seed differ widely from those obtained in 1957. The differences can probably be attributed to the weather in the eight to ten weeks following sowing, which in 1957 was dry but in 1958 was wet for the greater part of the period. In both years, seed that had been pre-chilled, and seed which had been stratified for 3 to 6 weeks, has given good yields.

At Benmore, Bush, and Newton nurseries, *Abies balsamea*, *A. nobilis* and *A. lowiana* seed was used in four experiments in which the effects of stratification for one, two, three or four months, and "no stratification", on the yield and height growth of the resulting crop of seedlings were examined. All the seed was sown in early April, when it was found that the seed stored for the two longest periods was infected with a mould fungus and that in some cases, some of the seeds in these two treatments had developed sprouts. This caused a reduction in seedling numbers of *A. lowiana* at Newton and *A. balsamea* at Benmore. Stratification of *A. balsamea* at Bush, for a period of up to four months, did not result in an increase in seedling numbers, and had negligible effects on seedling heights. Stratification for 2 to 3 months increased the yield of *A. nobilis* and also gave an appreciable improvement in seedling heights, the increase being proportional to the length of the period in stratification. *A. lowiana* responded to a 1 to 2 month period of stratification by an increase in seedling numbers, but stratification did not improve height growth.

Long-term Fertility Demonstrations 232.322.1

The long-term fertility demonstration at Teindland Woodland Nursery continued into the ninth year. As in the past, both lodgepole pine and Sitka spruce were used as indicator species. Main treatments are inorganic fertilizers alone, hopwaste alone, combinations of the two, and untreated controls. (Table 4.)

Both species responded to the treatments in a similar manner. The combination of hopwaste and inorganic fertilizers produced the tallest seedlings, and this treatment was closely followed by "hopwaste alone". Inorganic fertilizers produced seedlings which were very much smaller. As expected, the control treatment produced the smallest plants. There were no significant differences between any of the treatments in yield of seedlings.

Table 4

Teindland Woodland Nursery Fertility Demonstration End of Ninth Year. Heights and Production figures for Sitka spruce and lodgepole pine one-year seedlings

Treatments	Sitka spruce			Lodgepole pine		
	Mean Height in.	No. per sq. ft.	% over 1½ in. tall	Mean Height in.	No. per sq. ft.	% over 1½ in. tall
Control: No fertilizer or hopwaste....	0.52	165	0	0.81	123	0
Inorganic fertilizer only	1.35	159	28	1.10	112	8
Hopwaste only	1.76	162	58	1.70	112	55
Inorganic fertilizer and hopwaste	1.86	138	64	1.94	120	74
Standard error ±	0.05	6	—	0.05	6	—
Critical differences: 5%	0.16	Not	—	0.17	Not	—
1%	0.24	Sigt.	—	0.27	Sigt.	—

The long-term fertility demonstrations at Newton and Fleet nurseries are in the second rotation, and are under two-year and one-year old Sitka spruce seedlings respectively. Partial soil sterilization with formaldehyde solution is included at both nurseries. At Newton (see Table 5), inorganic fertilizers had no effect on height when compared with the controls whereas hopwaste produced the greatest height increase of all the treatments. Both green crops and sterilization treatments increased the height of the seedlings but their effects were not cumulative. Green crops and hopwaste both reduced seedling yields.

At Fleet (see Table 6), inorganic fertilizers alone had no effect on seedling height but hopwaste and particularly hopwaste and inorganic fertilizers in combination, both increased the height of the seedlings. Sterilization alone and in combination with a green crop, produced much taller plants than either the green crop alone or the controls. As at Newton the bulky organic fertilizers (hopwaste and green crop) both caused a reduction in seedling numbers when compared with other treatments. The fact that inorganic fertilizer applications were ineffective at both Newton and Fleet suggests that there is still an appreciable residue of fertilizers in those soils left over from soil treatments before the demonstrations were begun.

Table 5

Newton Fertility Demonstration. Contingency Table of Height and Production Data for Sitka spruce two-year seedlings

a = Mean Heights in inches. b = Total numbers per square foot.

Treatments	Control		Artificial Fertilizers only		Hopwaste only		Artificial Fertilizers & hopwaste		Mean		S.E. ±
	a	b	a	b	a	b	a	b	a	b	
Control	2.24	77	2.12	101	5.10	88	5.00	68	3.62	84	0.16 6
Greencrop	2.94	94	2.38	84	7.40	73	5.56	65	4.58	79	0.16 6
Sterilization	2.30	87	2.44	98	6.38	79	6.20	78	4.34	86	0.16 6
Greencrop and sterilization	2.70	82	2.72	81	6.94	78	6.00	77	4.58	80	0.16 6
Mean	2.55	85	2.42	91	6.46	80	5.69	72	4.28	81	0.13 8
S.E. ±	0.16	6	0.16	6	0.16	6	0.16	6	0.13	5	—

Table 6

Fleet Fertility Demonstration. Contingency Table of Height and Production Data for Sitka spruce one-year seedlings

a = Mean Height in inches. b = Total Numbers per square foot.

Treatments	Control		Artificial Fertilizers only		Hopwaste only		Artificial Fertilizers and hopwaste		Mean		S.E. ±
	a	b	a	b	a	b	a	b	a	b	
Control	1.58	100	1.68	86	1.88	88	1.95	95	1.77	92	0.13 8
Greencrop	1.15	104	1.05	103	1.78	95	1.75	97	1.43	100	0.13 8
Sterilization	1.95	92	2.02	86	2.48	67	2.98	81	2.36	81	0.13 8
Greencrop and sterilization	1.98	125	1.80	113	2.80	95	3.90	118	2.62	113	0.13 8
Mean	1.66	105	1.64	97	2.23	86	2.64	98	2.04	96	0.08 3
S.E. ±	0.13	8	0.13	8	0.13	8	0.13	8	0.14	2	—

The long-term fertility demonstration at Elvetham, Bramshill Forest, was continued for the eighth year. In this trial, plots receive (i) bracken/hopwaste compost at 20 tons per acre, (ii) potassic superphosphate at 6 cwt. per acre (14 lb. per 100 sq. yd.)+two summer top dressings of 'Nitrochalk' at 2½ cwt. per acre per dressing (6 lb. per acre per dressing); (iii) compost as in (i)+inorganic fertilizers as in (ii); (iv) no fertilizer. All plots are sown with Sitka spruce. The mean height of first-year Sitka spruce seedlings in October, 1958 are given in Table 7.

Table 7

Elvetham Nursery, Bramshill Forest—Long-term Fertility Demonstration. First-year Sitka spruce. Seedling Heights and Numbers. October, 1958

Treatment	No. of Seedlings per square yard		Mean Height. In.	
No fertilizer	710	S.E.	1.06	S.E.
Inorganic fertilizer	722	±47.6	1.75	±0.063
Bracken/hops compost	726		2.21	
Inorganic fertilizer+compost	588		2.20	

Seedling numbers were appreciably but not significantly lower on plots receiving compost plus inorganic fertilizers. Tallest seedlings were grown on plots receiving compost alone or compost plus inorganic fertilizer. This is the third successive year when seedlings on inorganic fertilizer plots have been significantly smaller than those on compost plots.

At Wareham nursery, the regime for the maintenance of fertility prescribed by Dr. Rayner was continued. This rotation is described in the *Report on Forest Research for* 1958. Growth on all parts of the experiment was good, and little discoloration of plants was noted on any treatment other than the second-year seedbeds, on the rotation that includes "hopwaste compost only". Here slight red and purple discolorations occurred in seedbeds of Norway spruce, Sitka spruce, Corsican pine and lodgepole pine.

Inorganic Fertilizers—Nitrogen 232.322.41

Experiments investigating whether heavy or late applications of nitrogen lead to lush growth and failure of plants to "harden-off" before the winter frosts, were continued both in Scotland and England. It had been hoped that the recent run of mild autumns would break, and that early frosts would damage some treatments more than others. However, the autumn of 1958 was extremely mild, and at none of the eight nurseries involved was any one treatment more affected by frost than the others.

In Scotland the experiments were carried out at Inchnacardoch, Tulliallan, Bush and Fleet nurseries. Nitrogen was applied at 0, 25 or 50 oz. per 100 sq. yd. of first-year seedbeds of Douglas fir or Japanese larch. The nitrogen was applied as 'Nitrochalk'. The "25 oz. per 100 sq. yd." treatment was applied as two equal top dressings in July (standard Scottish practice); and the "50 oz. per 100 sq. yd." treatment was applied as four equal top dressings, with two in July and two in August.

An assessment of the effect of the different rates of nitrogen on the date of terminal bud formation at Tulliallan and Bush showed that the lower (standard) rate of application delayed the formation of terminal buds and cessation of growth by approximately ten days. The higher rate of application delayed the formation of terminal buds by approximately twenty days. Differences were not pronounced at Fleet or Inchnacardoch.

In experiments in England at Kennington, Ampthill, Wareham and Bramshill nurseries, nitrogen was applied to Douglas fir and Japanese larch seedbeds at 30 and 60 oz. nitrogen per 100 square yards. The lower rate was applied as two equal dressings in early June and early July (i.e. standard practice in England and Wales for most conifer seedbeds), or in early August and early September. The heavier application was made at monthly intervals between early June and early September. Control plots received no nitrogen.

The formation of terminal buds of Japanese larch at all four nurseries was slightly delayed by applications of nitrogen in June and July; applications in August and September further delayed terminal bud formation to much the same extent. Bud formation of Douglas fir at Kennington and Bramshill progressed at the same rate on plots of all treatments; but at Ampthill and Wareham bud formation on *control* plots was much in advance of that on all *other* plots, between which there was no significant difference.

Neither rate nor date of application of nitrogen had any effect on numbers of seedlings of either species at any nursery. Tallest seedlings were found, as might be expected, on plots receiving most nitrogen.

Fertilizer Damage to Transplants

In a Conservancy nursery in South-east England, transplants lined-out in the autumn of 1956 and given a top dressing of a compound fertilizer containing 5% N, 12½% P_2O_5, 12½% K_2O, in spring 1957, had sustained more losses than normal. A small experiment designed to show whether the losses were due to the form, or to the time of application of the fertilizer, or to other causes, was carried out on Conservancy transplant lines at Elvetham nursery, Bramshill. Compound fertilizer with the same analysis as given above was applied either as a single application at 6 or 8 cwt. per acre in early March, early April or mid-April, or as two dressings each of 3 or 4 cwt. per acre, the first of the two dressings being put on in early March, early April or mid-April, and the second dressing 6 weeks after the first. Plants were brushed after application of fertilizer, to ensure that none of it lodged in the foliage, but no attempt was made to cultivate the fertilizer into the soil.

Damage to plants occurred, and assessments of the number of live plants of Norway spruce, Scots pine and Corsican pine are given in Table 8 below.

It will be seen that most plants were killed when the fertilizer top dressing was put on in early March, and that survival improved the later the fertilizer was applied. Fewest plants survived on plots given the highest rate of fertilizer; plots given two dressings of fertilizer at half-rate sustained less damage than when all the fertilizer was put on at one time.

There were substantial differences in the effect of the fertilizer on survival of different species; the table shows that Scots pine was less affected by fertilizer than either Corsican pine or Norway spruce. Other species included in the trial were European larch and Douglas fir, neither of which were affected by the top dressings, and Lawson cypress and Western red cedar, both of which were affected by top dressings in the same way as Norway spruce and Corsican pine.

Table 8

Number of 1+1 *Transplants Surviving at the End of the Growing Season* (140 *plants per treatment originally lined out*). *Elvetham Nursery, Bramshill. October*, 1958

Date of Application (or first application) of fertilizer	Rate of fertilizer applied			
	6 cwt.	3+3 cwt.	8 cwt.	4+4 cwt.
	No. of plants surviving treatment			
(a) *Norway spruce*				
Early March	85	95	76	82
Early April	94	118	78	96
Mid-April	105	122	102	101
	Control—no fertilizer 119			
(b) *Corsican pine*				
Early March	69	101	41	50
Early April	90	106	74	76
Mid-April	103	105	104	110
	Control—no fertilizer 104			
(c) *Scots pine*				
Early March	94	99	78	102
Early April	98	118	104	108
Mid-April	107	106	112	96
	Control—no fertilizer 110			

Date of Sowing 232.323.3

At Kennington, Bramshill, Ampthill and Wareham nurseries, seed of Sitka spruce, Corsican pine, Douglas fir and Western hemlock was sown at intervals of fourteen days commencing in the first week in March, and continuing until mid-May.

This series of experiments first carried out in 1952 has proved to be so useful when comparing growth on experiments sown at different times in one nursery that it is now repeated annually at the main English research nurseries.

At Ampthill and Wareham, the height of all species at the end of the season was greatest on the early sown plots and steadily diminished the later the plot was sown; numbers, though more variable, also decreased with later sowing. This height response has been observed regularly in date of sowing experiments, but plant numbers have often tended to increase rather than decrease with the later date of sowing. At Kennington nursery, there were no significant differences in seedling numbers of Douglas fir and Sitka spruce; heights of these two species tended to decrease irregularly with later sowing. The number of seedlings of Corsican pine and Western hemlock at Kennington increased with later sowing; the height of Corsican pine seedlings was unaffected by date of sowing, while the height of Western hemlock seedlings was extremely variable. At Bramshill, heights and numbers of seedlings of all four species showed no clear pattern.

Intensive Methods of Raising Seedlings—Dunemann Seedbeds 232.323.7

Dunemann seedbeds continue to arouse interest in private estates and in certain Forestry Commission areas in Wales. In 1957, a small bed was started at Kennington nursery, Oxford, in order to gain experience of the technique, and in 1958, the bed was sown for the second year. The spruce litter was made up to its original level with fresh litter, and seed of Sitka spruce, Japanese larch and Western hemlock sown in mid-April and early May. Seed was covered with normal seedbed grit. The bed was kept permanently shaded and the sides were protected against entry by birds by light gauge wire netting. Water was applied whenever there had been less than 0.1 inch of rain in the preceding 24 hours. Table 9 gives the mean height of the seedlings raised, together with the mean height of the same species sown at comparable times in open ground in other experiments.

Table 9

Seedling Heights on Dunemann and Stock Seedbeds at Kennington, Oxford. October 1958

Species	Source	Date of Sowing	Mean Height
Sitka spruce	Dunemann bed	14th April	3.33 inches
„ „	„ „	5th May	3.04 inches
„ „	Date of Sowing Expt.	14th April	3.93 inches
„ „	Control Tr't. Irrigation Expt.	8th May	2.76 inches
Japanese larch	Dunemann bed	14th April	7.93 inches
„ „	„ „	5th May	6.58 inches
„ „	Control Tr't. Irrigation Expt.	24th April	7.26 inches
„ „	Standard Tr't. Nitrogen Expt.	10th April	8.93 inches
Western hemlock	Dunemann bed	14th April	2.79 inches
„ „	„ „	5th May	2.51 inches
„ „	Control Irrigation Expt.	24th April	2.94 inches
„ „	Date of Sowing Expt.	28th April	2.50 inches

It will be seen that all the seedlings on late-sown plots in the Dunemann bed are smaller than those on early-sown plots, but that all are broadly similar in height to those raised by conventional techniques. Seedling counts at the end of the season showed that germination and survival on the Dunemann beds was no better than on conventional open beds in other parts of the nursery.

Intensive Methods of Raising Seedlings—Polythene Covers to Seedbeds

Polythene sheet is widely used in horticulture to cover seed boxes and pans to hasten germination of the seed, partly by conserving moisture, and partly also by creating warmer conditions. At Alice Holt nursery, seedbeds were covered with polythene sheeting from the time of sowing until the first emergence of seedlings, or a month after first emergence, in order to determine whether this use of polythene could be applied on a large scale in forest nurseries. Plots were sown with stratified Douglas fir seed and Japanese larch.

Table 10 below shows the number and height of seedlings at the end of the growing season.

Table 10

Numbers and Heights of Japanese larch and Douglas fir Seedlings With and Without Polythene Sheet During the Germination Period. Alice Holt Nursery. October 1958

Treatments	Japanese larch		Douglas fir	
	End of season Nos.	Mean heights (in ins.)	End of season Nos.	Mean heights (in ins.)
	per sq. yd.		per sq. yd.	
No polythene covering	191	3.78	226	4.44
Polythene covering until the first seedlings emerged	185	3.89	223	4.83
Polythene covering until four weeks after first seedlings emerged	178	4.55	226	5.30
Standard Error	5.47	.161	8.73	.135

It will be seen that while the number of seedlings of either species was unaffected by treatment, the height of seedlings was increased on covered plots; seedlings of both species on the plots covered for the longer time were significantly taller than the others. This response was not foreseen. It was expected that any benefit from the covering would be in the direction of increased numbers of seedlings rather than increased height.

Irrigation 232.325.1

An experiment was repeated at Kennington nursery in which the effect of applying two water regimes to seedbeds of nine species was compared. In both regimes water was applied from date of sowing until the end of June at the rate of 0.20 inches of water whenever the estimated soil moisture deficit exceeded 0.25 inches; from July until the end of the season, in one regime watering was discontinued, while in the other, water was applied at the rate of 0.40 inches whenever the estimated soil moisture deficit exceeded 0.50 inches. Seed was sown in the experiment on the 24th April, and fourteen applications of water were made between sowing and the end of June. From July until the end of the growing season, only four more applications of water were made.

Nine species were sown, but seedling yields of only two species were affected by irrigation. *Abies nobilis* and western hemlock both germinated more rapidly and yielded more seedlings at the end of the season on plots receiving irrigation, than they did on unirrigated plots. The mean height of seedlings of eight of the nine species was moreover appreciably or significantly greater on irrigated plots. Japanese larch was the only species which failed to respond to irrigation.

Seed Dressings—Protection Against Fungi 232.315.4:232.327.2

In practice it is usually found that the number of seedlings produced per pound of seed is very much less than the germination percentage obtained from standard seed germination tests. The reasons for the differences are many, and may be due to pre- and post-emergence infection of the seed or young seedlings by fungi, to insects and birds, and to weeding operations. It is possible that pre-emergence losses by fungi may be of importance, and that these losses may be accounted for by fungi borne on the seed testa or by soil-borne pathogens. A series of experiments in 1948, which compared the effects of various proprietary seed dressings on seedling yields, produced no conclusive results. Since that time new and improved fungicides and insecticides for horticultural and agricultural use have been marketed, and five of these, namely, 'Panogen', 'Agrosan', 'Agrocide', 'Fernasan' and 'Griseofulvin', were selected for experimental use in the North. Each of them was applied at three concentrations to Scots pine, Japanese larch, Sitka spruce and silver fir seed; untreated seed was also used for comparison purposes. At the end of the first growing season, the seedlings were assessed for height growth and yield.

The results from the experiments were variable and inconsistent between nurseries. No treatment at any centre produced a yield of seedlings which approached the estimated number of viable seeds sown, but no treatment had a harmful effect on seedling heights. Post-emergence losses were negligible in all the experiments, and it is concluded that seed-borne fungi are not particularly important causal agencies for seed and early seedling losses, and that soil-borne fungi may be more important.

At Kennington and Alice Holt nurseries, a joint enquiry with the Pathology Section was carried out into the effect of thiram (tetra-methyl-thiuram-disulphide) applied as a seed dressing alone, or applied as a seed dressing followed by a fortnightly drench of water containing thiram. Seedbeds at Kennington were sown with Douglas fir and at Alice Holt with Sitka spruce. The seed dressing was a dust containing 50% thiram, and was applied at the rate of 2 grams dust per pound of seed. The drench was applied at the rate of 27.5 grams wettable powder containing 80% thiram in ½ gallon water per square yard. The drench treatment was applied at fortnightly intervals, commencing a fortnight after sowing until the end of June.

Two other treatments included in the experiment were (a) control—no fungicides and (b) a potassium permanganate spray at the rate of 1 oz. potassium permanganate dissolved in 2 gallons water applied over 6 square yards. Potassium permanganate solution was applied at the first sign of damping-off, and was repeated at intervals of three to four weeks until July.

A count of seedlings dying was made, commencing with the first appearance of damped-off or dying seedlings and continuing until no further deaths occurred. Table 11 gives the results of these counts.

Table 11

Number of Dead Seedlings Removed During the Summer

Treatment	Number of dead seedlings per square yard	
	Kennington 18th May—30th June Douglas fir	Alice Holt 9th June—25th Aug. Sitka spruce
Thiram seed dressing only	17.5	4.0
Thiram seed dressing+drench	54.2	288.7
Pot. permanganate	17.2	5.7
Control—untreated	16.0	11.0

At neither nursery were the losses due to damping-off serious, nor were they affected by potassium permanganate or by thiram seed dressing treatments. However, thiram drench applications were harmful, and very significantly increased the number of dead seedlings removed.

While this did not result in a significant decrease in the numbers of Douglas fir seedlings surviving at the end of the season at Kennington, the numbers of Sitka spruce seedlings in the Alice Holt experiment were very significantly reduced in the plots that had had the "thiram seed dressing plus drench" treatment. In both nurseries, this treatment resulted in significantly smaller seedlings.

Protection Against Birds 232.327.3

Dieldrin is a recently-developed insecticide which has been observed to act as a bird repellent. Experiments to examine its effectiveness were carried out at Bramshill; in both an intensive experiment and an extensive experiment, plots were sprayed with dieldrin at the rate of ½ gallon miscible oil containing 15% dieldrin in 100 gallons of water per acre. The first spray was applied on April 23rd, and sprays were repeated at 14-day intervals during the germination period. Control plots were either left untreated or were protected with ¾-inch mesh wire netting. In the small-scale intensive experiment, Corsican pine was sown on April 22nd. The extensive experiment was carried out on Conservancy stock beds of Corsican pine and Scots pine sown in late March.

Table 12 gives the number of seedlings per square yard on 20th May and at the end of the growing season in the intensive experiment and the numbers at the end of the growing season only, in the extensive experiment.

Table 12

Number of Seedlings per Square Yard on Plots in Bird Repellent Experiment, Bramshill

Treatment	Corsican pine intensive		Corsican pine extensive	Scots pine extensive
	May	October	October	October
Unprotected	5.0	12.5	58.7	225.6
Wire netting	241.0	339.3	75.8	206.7
Dieldrin spray	6.7	16.7	52.6	218.7

Damage was serious in the intensive experiment, and no benefit was obtained from the dieldrin sprays. In the extensive experiment, there was little or no damage after April 23rd, when treatments were applied.

Weed Control in Seedbeds 232.325.24

(*a*) *CIPC, monuron and tar acids.*

Experiments were carried out at Kennington and Ampthill testing CIPC*, monuron* and a proprietary formulation of tar acids. At Kennington, seedbeds were sown with Sitka spruce; at Ampthill, Japanese larch was sown.

* For full name and description of these materials see "Weed Control" published 1958 by Blackwell, Oxford, for the British Weed Control Council.

CIPC was applied at 2½, 5 and 10 lb. per acre before sowing, monuron at 1, 2 and 3 lb. per acre before sowing, while the tar acids were applied at 2½, 5 and 10 gallons formulation per acre 3-4 days before seedling emergence. All materials were diluted with water and applied as sprays.

Both CIPC and monuron severely damaged the germinating seedling crop at all rates of application at both nurseries. This is in strong contrast to the results obtained in the previous year, when the same materials at the same rates did little damage to the conifer crop, but gave reasonably good control of weeds.

Tar acids at 5 and 10 gallons formulation per acre gave as good weed control as vaporising oil, and did no damage to either crop. The cost of tar acids for the lower rate of application is 30-40% greater than the cost of vaporising oil for a pre-emergence spray.

(*b*) *NPA**

NPA (N-1 Napthylpenalamic acid) was applied as a pre-emergence and post-emergence spray in experiments at Bramshill and Kennington on seedbeds of Corsican pine and Sitka spruce respectively. NPA was applied at the rate of 3, 6 and 9 lb. sodium salt per acre, 3-4 days before seedling emergence, and at intervals of 4 weeks commencing 6 weeks after the pre-emergence spray. The pre-emergence application at each rate significantly reduced the number and height of Sitka spruce seedlings at Kennington, while at Bramshill, the number of Corsican pine seedlings was significantly reduced by applications of NPA at 6 and 9 lb. per acre. Post-emergence applications of NPA also significantly reduced the number and height of Sitka spruce seedlings; Corsican pine seedlings were unaffected by any post-emergence application of NPA. The weeding times on plots sprayed with NPA at 3 lb. before seedling emergence was significantly greater than on plots given a pre-emergence spray of vaporising oil at 60 gallons per acre at Kennington, but not at Bramshill. Weeding times on pre-emergence spray plots at the two higher rates of NPA did not differ significantly from the times on plots sprayed with vaporising oil; the weeding time on plots given a post-emergence application of NPA did not differ significantly from untreated plots weeded by hand.

(*c*) *Frequency of Weeding.*

Douglas fir seedbeds at Ampthill, and Sitka spruce seedbeds at Bramshill, were weeded by hand at intervals of 2, 4 or 8 weeks following pre-emergence spraying, in order to obtain evidence of the harmful effect of delayed weeding on crop yields. Table 13 gives the number and height of seedlings at the end of the growing season, the time taken to weed each plot, and the number and weight of weeds removed.

Whilst neither the numbers nor heights of seedlings were affected by the frequency of weeding, plots weeded at eight-week intervals took very much longer to weed over the whole season, than did those weeded at shorter intervals. Weeds removed at eight-week intervals were larger and more numerous than those encountered at the shorter intervals (two and four weeks), between which times there was little difference in this respect.

The results of this experiment agree very closely with those from a similar experiment carried out in 1957 and described in the *Report on Forest Research*, 1958, page 35.

* For full name and description of these materials see "Weed Control", 1958.

Table 13

Seedling Heights and Numbers: Numbers, Weights and Removal Times of Weeds. "Frequency of Weeding" Experiment—Ampthill and Bramshill Nurseries

Frequency of Weeding	Number of Seedlings per sq. yd. at end of season		Mean height of seedlings at end of season Inches		Total weeding time Minutes		Total number of weeds removed				Total weight of weeds removed Grams.	
	D.F. Ampt.	S.S. Bram.	D.F. Ampt.	S.S. Bram.	Ampt.	Bram.	Ampt.	Ampt. Transformed*	Bram.	Bram. Transformed*	Ampt.	Bram.
Interval of 2 weeks	568	1216	3.88	2.01	9.5	9.1	56	7.50	110	10.53	5.2	21.5
Interval of 4 weeks	576	1382	3.73	2.14	8.1	7.3	61	7.86	98	9.90	25.4	43.4
Interval of 8 weeks	572	1213	3.50	2.02	20.3	12.1	256	16.01	166	12.92	333.0	283.6
Standard Error	18.5	41.9	0.23	0.075	3.09	1.22	—	1.83	—	0.52	49.0	35.3

Notes: D.F.=Douglas fir. S.S.=Sitka spruce.
*=Transformed by $\sqrt{(x+0.5)}$.

While the damage to crops that can be caused by delayed weeding is generally appreciated, the saving in weeding costs that can be achieved by weeding at regular intervals of about a month has not previously been so clearly demonstrated.

Weed Control in Transplant Lines

(*a*) *Simazin and Diquat*

Simazin* and diquat (1, 1′ ethylene—2, 2′ dipyridylium dibromide) were both applied as inter-row sprays to transplants of Scots pine, Sitka spruce, Douglas fir, Japanese larch, ash, birch and *Tsuga mertensiana* at Alice Holt nursery. Both materials were applied in early August as a directed spray, between the rows of plants at rates of ½, 1 and 2 lb. per acre of diquat and 1 and 2 lb. per acre of Simazin, all applied in water at the rate of 60 gallons of spray per acre. Neither material did any damage to any species in the trial. No information on the control of weeds by either material was obtained from this experiment, as the population of weeds in the nursery before spraying was extremely low.

(*b*) *Fenuron, CIPC and* 2,4-*DES.*

At Kennington and Bramshill nurseries, fenuron*, CIPC* and 2,4-DES* were applied to transplants of Sitka spruce and Douglas fir at Bramshill, and Sitka spruce and lodgepole pine at Kennington. Fenuron was applied at ½, 1, 1½, 2 and 2½ lb. per acre; CIPC at 1, 2, 3, 4 and 5 lb. per acre; and 2,4-DES at 1½, 3, 4½, 6 and 7½ lb. per acre. Plots were sprayed with two materials so that every combination of rate of fenuron and CIPC, and fenuron and 2,4-DES, was applied at both nurseries; in addition, at Bramshill, every combination of rate of CIPC and 2,4-DES was applied.

No crop damage was attributable to any rate of CIPC or 2,4-DES on any species in the experiment. The height of Sitka spruce and lodgepole pine was lower when fenuron was applied at 2½ lb. per acre, but the height of Douglas fir was unaffected. Needle scorch was observed on Sitka spruce, and yellowing on the tips of lodgepole pine needles, on plots receiving fenuron at rates of 1½—2½ lb. per acre.

* See "Weed Control", 1958 for full details of these materials.

Fenuron was most effective in reducing weed growth; at 1 lb. per acre weeding times were reduced by two-thirds at Bramshill, and by one-third at Kennington. At 2½ lb. per acre, weeding times were reduced by a further 15% at Bramshill, and by a further 6% at Kennington.

CIPC at 2 lb. per acre reduced weeding times by 45% at Bramshill, and by 40% at Kennington; at 5 lb. per acre weeding times were further reduced by approximately 10% at both nurseries.

2,4-DES gave little weed control at Bramshill. At Kennington, at 3 lb. per acre, weeding times were reduced by 22%, while at 7½ lb. per acre, weeding times were reduced by a further 12%.

At neither nursery was there any evidence that weeds were controlled more effectively because of the application of two materials together.

(c) *Polythene, Sisalkraft Paper and Tinfoil*

At Bramshill, black polythene sheeting, sisalkraft paper and tinfoil placed between the rows of transplants of Corsican pine, hybrid larch, Douglas fir and Norway spruce was used to control weed growth. No material had any effect on plant growth, nor was the weeding time reduced, largely because of the need to hand weed between transplants and along the edges of the various forms of sheeting. Handling the strips into position between lines of plants at 8-inch spacing was difficult; the sisalkraft paper was easiest to handle and the tinfoil most difficult. Strips were held in position with builders' laths at 18 inches across the strips, and by occasional large stones. During the season, it was found that the black polythene stayed where it was, the sisalkraft paper tended to curl at the edges, while the tinfoil was punctured by stones in the soil when trodden on. In view of the poor weed control, the difficulty of placing the various forms of sheeting and their cost, there appears to be no future for the use of these materials in forest nurseries.

Weed Control in Poplar Lines: Vaporising Oil, PCP and Monuron

Vaporising oil at 60 and 120 gallons per acre, PCP* (pentachlorophenol) at 2 and 4 lb. applied in 100 gallons of water per acre, and monuron* at 2 and 4 lb. in 100 gallons of water per acre, were applied to stumped rooted cuttings of *Populus serotina* V.B. at Alice Holt nursery, and at Nagshead nursery in the Forest of Dean. Materials were applied (a) before shoot emergence, (b) before shoot emergence and whenever necessary thereafter, (c) before shoot emergence and whenever necessary commencing 6 weeks thereafter, and (d) before shoot emergence and whenever necessary commencing 10 weeks thereafter.

Three applications of PCP and vaporising oil had to be put on most plots during the growing season, but only one (or two) of monuron. No plants were damaged by any treatment applied at any date of application. Best control of weeds was on plots sprayed with monuron at the higher rate; next best were plots sprayed with monuron at the lower rate.

Maleic Hydrazide for Growth Control 232.329.9

Applications of 0.4%, 0.2%, 0.1% and 0.05% solutions of maleic hydrazide in water at the rate of 15 pints per 100 sq. yd. of seedbed, were applied to rising two-year-old seedlings of beech, with the object of checking growth. These treatments, which had proved effective in earlier experiments with various

* See "Weed Control", 1958 for full details of these materials.

conifer seedlings, had no effect on the growth of the beech. The sprays were applied in spring when the seedlings had approximately five fully developed leaves.

Handling and Storage of Plants in Polythene Bags 232.412.4

A number of experiments on the effect of storing plants in polythene bags was carried out at Kennington, Bramshill, Alice Holt and Wareham nurseries. Results were very similar to those obtained in 1957 and have been described elsewhere (Aldhous, 1959).

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SILVICULTURAL INVESTIGATIONS IN THE FOREST

(A) SOUTH AND CENTRAL ENGLAND AND WALES

By R. F. WOOD and G. D. HOLMES

Afforestation Problems

Ground Preparation and Planting Methods

No new experiments were started during the year, but observations were continued on the large trials of ploughing methods laid down in 1956 and 1957 at Wareham, Purbeck, Haldon, Croft Pascoe and Taliesin forests. These trials are mainly concerned with varying intensities of cultivation and their effects in terms of long-term crop increment. Assessments after the third growing season at Croft Pascoe, Wareham, and Haldon indicate that complete ploughing is superior to single-furrow ploughing, and a much more widespread root system is developed. Complete ploughing seems advantageous in slowing down the rate of re-invasion of vegetation, notably heather and gorse, and providing favourable rooting conditions for a planted crop. However, drainage may be a problem in some conditions, and open plough drains may be necessary.

The effects of deep sub-soiling, in addition to surface cultivation, are also tested, but effects are likely to be long-term and no crop-growth effects have appeared to date.

Afforestation Problems on Particular Types of Land

Little new work was initiated on this project. Detailed inspections were made of the problems of afforesting disused gravel workings, and areas of spoil from copper and tin mining operations in South-west England, and trials may be started on these types.

Work was continued on the problem of Southern and Western heath types at the experimental centres of Wareham and Croft Pascoe. At Croft Pascoe, on shallow exposed heath over serpentine rock, intensive cultivating and phosphate application appear to be prime requirements for successful forest establishment. However, as indicated below, heavier than normal phosphate dressings appear necessary to ensure sustained growth on these very deficient soils. Many of the plots manured at the standard rates of 1½-2 oz. superphosphate per plant, are now falling off in growth, and will require top-dressings to prevent a growth check. Of the 24 species tested at this centre, *Pinus radiata*, lodgepole pine, and *Pinus pinaster* are outstandingly the best, with Sitka spruce not far behind providing adequate phosphate is applied. *P. radiata* is the most promising species, but the difficulty of securing a high survival rate from planting remains a practical drawback with the species. In this connection, very striking results were obtained in "season of planting" experiments with this species, September and October being much superior to other seasons.

At Taliesin forest, a series of crop establishment experiments have been formed on a site representative of a large area of steep freely-drained mineral soils over shale in Wales. Most of the experiments were planted in 1956, and so far, Sitka spruce, *Abies nobilis*, and lodgepole pine are the outstanding species.

Afforestation of Exposed and Elevated Sites

As noted in the last report, preliminary steps were taken in initiating a survey of existing older woods on limiting sites on both privately owned and Commission land. A first enumeration of old exposed stands shows that in the great majority of cases the species present are oak, beech, Norway spruce or European larch, none of which would be regarded today as an outstanding candidate for elevated and exposed sites. This places a severe limit on the immediate practical value of the information from a detailed survey. Useful general information will be forthcoming, but this will in no way detract from the need for a more complete series of species pilot plots particularly in Wales and South West England.

Forest Stand Improvement

Manuring at Planting

Experiments, planted in 1956, testing phosphate and potash dressings on poor mineral soils confirm the benefits of phosphate, but have failed to bring out any measurable effect of added potash on tree growth. On the poorest mineral soils such as at Croft Pascoe and Wilsey Down Forests in South-west England, it is evident that the usual rates of 1½-2 oz. ground mineral phosphate or superphosphate per plant are inadequate to ensure continuing growth of the crops. Experimental applications at rates from 2-16 oz. superphosphate per tree show marked growth improvement with the higher rates; but it remains to be seen whether single heavy dressings will make it possible to dispense with further applications later in the life of the crops.

Improvement of Checked Plantations

Investigations were continued at Tarenig, Haldon, Wareham, Ringwood, and Wilsey Down Forests, into methods of improving the growth of checked and slow-growing crops of pine and spruce. Fortunately these problem sites are of limited area, but nevertheless they are of considerable local importance as they carry unproductive crops with a high fire risk.

In Wales, observations are being made in poor spruce crops at several forests, notably Tarenig, Myherin, and Halcyn (Coed Clwyd) Forests. Here most of the problem areas are located on compacted freely-drained mineral soils over shales. Nutrient deficiency, and competition from the heavy vegetation of gorse and heather, are probably major factors restricting growth. Soil phosphate levels are somewhat marginal, ranging from 400-800 p.p.m. total phosphate. Manuring and vegetation control trials are now under way at all the major centres. The earliest experiments established in 1956 at Tarenig show a marked improvement of Norway and Sitka spruce following broadcast phosphate dressings. In view of this early promise, further trials are being made to determine optimum rates of application before large-scale treatments are considered.

On the infertile sandy heaths at Wareham and Haldon forests, work on crop nutrition and control of competing vegetation in poor Scots and Corsican pine crops shows promising results. At Haldon, phosphate broadcast in 1956 has resulted in a dramatic improvement of growth of Scots and Corsican pine, and chemical eradication of heavy *Calluna* growth has enhanced this effect. Parallel trials on both pines at Wareham show similar results. Lime and potash dressings have produced no apparent effect, but phosphorus and nitrogen dressings had marked growth effects.

In *Calluna*-dominated ground, the crop response to phosphate is greatly increased when the phosphate dressing is combined either with *Calluna* eradication or nitrogen dressing. Clearly, improved nitrogen supply is necessary on these sites in order to obtain the maximum crop response to added phosphate. In these first experiments nitrogen has been applied as 'Nitrochalk' at 45 to 225 lb. nitrogen per acre, and although there is a pronounced crop response in colour and growth, the effects persist for only two seasons. Repeated annual dressings at 45 lb. nitrogen per acre show a sustained effect, but frequent dressings are obviously impractical for large-scale work.

These observations re-emphasise the need for a more persistent form of nitrogen than the conventional sulphate and nitrate fertilizer salts for forest use. There is evidence, (Hinson, W. H. and Reynolds, E. R. C., *Chem. & Indus.* 1958, pp. 194-6), that compounds such as urea and ammonium phosphate may be less readily leached from humose soils. Test dressings have been made this year to gauge the persistence of crop effects with these forms. These tests have been combined with a range of rates of phosphate, as triple superphosphate, to provide accurate information on phosphate dose requirements with a view to practical scale treatments. Also in 1959, two experiments were started to determine the effects of N, P, and K dressings on needle-fusion "disease" of thicket and pole-stage lodgepole pine at Wareham and Ringwood. This "disease" is of little practical significance as the areas of lodgepole pine on these sites is negligible. However, there is evidence that the disorder is basically nutritional and it is felt that observations of the effect of mineral fertilizers should be of value, with a bearing on the nutrition of pine in general.

Work has also continued on the checked spruce crops planted in the early 1930's on the phosphate-deficient Culm soils at Wilsey Down and Halwill. Crops receiving broadcast dressings of potassic superphosphate at 2, 6, and 12 cwt. per acre in 1954 continue to grow vigorously. At the 6 cwt. rate, the crop has now closed canopy, trees ranging from 5-12 ft. high compared with unmanured trees, which remain in check at 1½-2 ft. high in dense *Molinia*, *Ulex*, and *Calluna*. PK factorial trials have confirmed that this response is almost entirely attributable to phosphate. Similarly, rates tests indicate that a sustained response can be achieved at rates of 70 lb. phosphate (3 cwt. triple superphosphate) per acre, and over. Broadcasting appears to be the most effective method of application, and trials with placed dressings at equivalent rates show less uniform crop responses.

Checked and slow growing spruce at Wilsey exhibit an unusual summer wilt or droop of young shoots. This symptom disappears after phosphate treatment, but may re-appear in two years following applications as low as 21 lb. phosphate per acre. The symptoms are closely similar to those ascribed to trace element deficiencies for many crops, but foliar spraying of copper, zinc, boron, and molybdenum in 1958 has failed to remedy the condition. As a result of the large and sustained improvement of growth with phosphate dressings in the period 1954-57, it was decided, in 1959, to proceed with practical treatment of 100 acres of the worst checked areas at Wilsey Down and Halwill. In view of earlier experience of the difficulties with ground spreading equipment, dressings were applied with a fixed-wing aircraft. As this was the Commission's first experience with aerial methods of applying fertilizers in forests, the whole operation was regarded as an experiment in technique and costs. The operation proved entirely successful, the dressing of 3 cwt. triple superphosphate per acre being effectively spread from the air at an estimated cost of £1 per acre for the spreading, and £6 for spreading plus fertilizer. Based on this experience, there seems little doubt that for plantation crops, where the trees are an obstacle to ground equipment, aircraft provide an efficient and relatively cheap means of fertilizer spreading. It was found that the placing and rates of application could be controlled accurately. In fact, the aircraft was used successfully to lay down an N.P.K. factorial trial with 1-2 acre unit plots in thicket stage crops of spruce and pine at Wilsey and Halwill.

Poor growth of Douglas fir on the acid, silty soils of the central Weald of Kent, and Sussex also presents practical problems. Mineral deficiencies, especially phosphorus, potash and calcium, and rooting difficulties on the fine-textured soils appear to be the main factors limiting growth. The main problem areas are being surveyed in 1959, and experiments have been laid down testing N, P, K, and Ca applied to a range of unsatisfactory crops.

Nutrition of Pole Stage Crops

As noted in the last report, the first of a series of experiments to examine the effects of improved nutrition on the volume increment of established pole stage crops was laid down in 1958. These preliminary trials were restricted to low-quality Scots pine crops on impoverished Eocene soils at Wareham, Haldon, and Bramshill forests. Little is known of the effects of major nutrient additions to crops at this stage of development, and the first trials are somewhat complex factorial tests of N, P, K, Ca and Mg applied at 2 rates in a 3^5 factorial, 1/3rd replicate design. In addition to girth and height measurements, assessments include analysis of sample shoots to follow changes in crop nutrient levels in relation to treatment. The vernier girth bands for precision readings of girth increment, described in the last report, are proving of great value in these experiments for recording seasonal patterns of girth increment.

In 1959, a second series of experiments was established in spruce crops at the first or second thinning stage, over a wide range of conditions from Quality Class V to Quality Class II sites. These trials are located at eight forests in the main spruce growing areas in the West and South-west. In addition single experiments were started in selected low-quality pole crops of Douglas fir at Hemsted forest, and Corsican pine at Pembrey forest. The 1959 experiments have been simplified by omission of rates of application as a variable in the inquiry. The experiments are tests of N, P, K, Ca and Mg, each applied at a single selected rate in a 2^5 factorial, $\frac{1}{2}$ replicate design.

The problem of rapid solution and low persistence of conventional N and K fertilizers is of major importance in all forest manuring work. The present trials of forms of N have been mentioned, and trials are also proceeding with potash fertilizers specially formulated and granulated in pellets up to 10-15 mm. diameter, in order to slow down the rate of solution and loss after application.

Weed Control

Total Control

Control of inflammable herbaceous and grass vegetation in fire traces is an important requirement in many forest areas, and in 1956/57 extensive trials were laid down to examine the value of a number of non-selective herbicide treatments, including sodium chlorate, sodium arsenite, borax, borax/chlorate, monuron, and di-uron. More recently the trials have been extended to include simazin as a total herbicide, and 2,4-D, 2,4,5-T, and dalapon as translocated selective herbicides.

Results have varied greatly according to soil texture and species, but in most instances it was apparent that non-selective herbicides are most likely to be economic when used as *maintenance* treatments on sites where the established vegetation has been cleared by cultivation or by use of a translocated selective herbicide such as 2,4-D, 2,4,5-T and dalapon. On fire traces where tractor-drawn equipment can be utilised, mechanical cultivation followed by grading and gang mowing appears the most economic and satisfactory treatment. However, on steep or rocky ground, chemical preparation and maintenance of fire traces probably has an important practical place. Where total weed destruction by herbicides is required, e.g. fire traces, fence lines, and paths, the most economic procedure depends on the density of vegetation at the time of treatment. With a well-established cover of broadleaved and grass herbage, the indicated treatment is 2,4-D/2,4,5-T @ 3 lb. (acid)+dalapon @ 7 lb. (acid) per acre for initial control, followed by maintenance treatments with simazin @ 8-10 lb. ac. If weed cover has been removed by cultivation, simazin applied directly to the soil surface has given high degrees of weed control for periods of 12-18 months. It is clear that the persistent soil-acting total herbicides, such as simazin and monuron, are most efficient when used after removal of top growth mechanically, or chemically. The need for an efficient 'knock-down' treatment on established herbage has led to tests of a new translocated total herbicide, 1:1′-ethylene—2:2′ dipyridilium dibromide (F.B.2) for this purpose. Following mid-summer applications to mixed broadleaved and grass vegetation at 2-4 lb./ac., the main effect has been a severe temporary check to growth, with rapid recovery in the late summer. It was noted with interest that on grasses, especially

Molinia, the inflammable dead top growth found following treatment with 'F.B.2.', appeared to break down and disappear very rapidly. This effect was most striking compared with the persistence of dead tops following dalapon or amino-triazole treatment. It seems possible that F.B.2 could be of practical value as an adjunct to selective grass-killing herbicides, to reduce the fire hazard following treatment.

Control of Grass Weeds

During 1958 a series of experiments were started to examine the practical value of herbicides for controlling established grass swards in the forest, in preparation for planting and in the early years after planting. The first trials were carried out on a variety of vegetation types including downland grasses. (Friston and Marden Forests), woodland grasses (Alice Holt) and pure *Molinia* (Bramshill).

The main treatments tested were dalapon at rates of 5 lb. to 20 lb. (acid)/acre, as a selective, translocated and non-persistent grass herbicide, and simazine at 2½-10 lb./ac. as a persistent soil-acting total herbicide. Subsidiary tests were also made on some grasses using amino-triazol or simazin in mixture with dalapon.

On downland grass swards consisting notably of *Bromus*, *Festuca*, *Dactylis* and *Brachypodium*, early summer spraying with dalapon at 10-20 lb./ac. gave a high degree of control. Total vegetation cover was reduced from 100% to 15-40% by late summer, the surviving plants being mainly broadleaved herbaceous species. simazin applied pure or in mixture with dalapon at rate exceeding 5 lb./ac. added little to the grass control obtained with dalapon, but effectively reduced the number of broadleaved species surviving. Simazin is likely to be most interesting in the second season, when its persistent properties may assist in retarding recolonization of treated ground. Treatment of *Deschampsia*, *Agrostis*, *Agropyron* and *Holcus* in felled woodland areas shows broadly similar results. Dalapon at 10 lb./ac. gave over 80% kill of established grasses, while doubling the rate to 20 lb./ac. gave an increase to only 85-90% kill. A complete 100% kill of grasses appears most difficult to achieve at anything near economic application rates. Dalapon at 10 lb.+simazin at 5 lb./ac. was highly effective, although costly when applied as an overall treatment.

Molinia and *Nardus* proved to be highly susceptible to dalapon, and an almost complete kill of vigorous tussocks was obtained at 10 lb./ac. A mixture of amino-triazol and dalapon, applied at the same total acid equivalent to the dalapon treatments, showed more rapid kill of *Molinia*; but the final end of season effects appear similar to dalapon alone, as shown in Table 14.

These preliminary results indicate that there are differences between grass species and their susceptibility to dalapon treatment. Thus, *Agrostis*, *Bromus*, *Dactylis*, *Deschampsia*, *Nardus*, and *Molinia* were susceptible to early summer rate of 10 lb./ac. *Festuca* and *Holcus* on the other hand proved more difficult to control.

In all instances where high degrees of grass sward control were achieved, the grass top growth collapsed to produce a mulch-like mat at the soil surface, which tended to reduce the rate of seedling invasion following treatment. This mat was easily removed and provided excellent conditions for direct planting. Nevertheless one of the most striking later features of the results has been the vigorous development of broadleaved species present in plots in which the grass has been killed selectively. In particular, broadleaved herbaceous species develop rapidly and dominate the site within 8-10 months of successful grass eradication.

Table 14

The Toxicity of Dalapon and Dalapon+Amino-triazol to Molinia and Nardus

(Treatments applied June, 1958)

Treatment	% Survival	
	August	October
Dalapon @ 5 lb. (acid)/ac.	70%	20%
„ 10 lb. „ „	35%	1%
„ 20 lb. „ „	10%	0
Dalapon @ 2½ lb.+Amino-triazol @ 2½ lb./ac.	20%	10%
Dalapon @ 5 lb.+Amino-triazol @ 5 lb.	5%	0
„ 10 lb.+Amino-triazol @ 10 lb.	3%	0

Complete eradication of all vegetation including broadleaved herbaceous species is clearly an impractical and probably undesirable goal. However, there is little doubt that a dense and continuous grass cover is a more serious obstacle to rapid tree growth than a full cover of broadleaved weed species, although the effect of selective grass control by herbicides in this respect still remains to be proved.

Several treated plots have now been planted to test the effects of the vegetation change, and of any residual chemicals, on the survival and early growth of trees. Also, in several trials the treatments were applied as directed sprays to grass in existing crops of oak and Norway spruce (age 3-5 years), newly planted *Populus robusta*, and 30-year-old checked and stunted ash and sycamore in heavy grass cover. In all instances, the tree species have shown a high degree of resistance to spray injury. The only damage recorded was on 5-year-old Norway spruce, which showed some discoloration and death of the youngest needles at the tips of current shoots. Buds appear to have been unaffected. In the current season, trials are being extended to test the susceptibility of young trees, less than 5 years old, of species including Corsican pine, Scots pine, Norway spruce, Douglas fir, beech, oak, poplar, and cherry, to directed sprays applied for grass control after planting. Until the results of the latest trials are available, no recommendations can be made for post-planting spraying. However, for grass control prior to planting, useful control of a variety of species can be achieved with dalapon at 10 lb. per acre in early summer, without injury to trees planted in the subsequent autumn or spring.

It may be possible to economise in chemicals by restricting sprays to strips along the future planting lines, and this is being investigated.

Control of Woody Growth

Recommendations on chemical control methods for the more important woody species have been available since 1957. As stated in the last report a great deal is now known about the susceptibility of the common woody weed species to 2,4-D and 2,4,5-T, but insufficient experience is available on large-scale applications to permit accurate cost estimates to be made. During 1958, five Conservancies in England and Wales carried out practical scale applications of 2,4-D and 2,4,5-T for controlling woody and herbaceous vegetation in preparing ground for planting. The operations included foliage spraying of low growth, basal bark treatment of standing growth, and treatment of stumps after cutting, all carried out with a view to obtaining information on costs and the silvicultural value of these techniques.

Summer foliage spraying for control of bramble, heather, and unwanted hardwood and herbaceous growth was the most widely applied treatment. Using 2,4,5-T, or mixed 2,4-D/2,4,5-T, ester emulsions in water at 3-4 lb. (acid) per 100 gallons, total costs with knapsack sprayers ranged from £4-£9 per acre according to conditions and volumes of spray applied. Good control has been achieved in many instances, and at the costs indicated these chemicals seem to have a practical place for pre-planting weed control. Stump treatments of freshly cut hardwoods with 2,4,5-T in oil, or with aqueous solutions of ammonium sulphamate, also show promise in practical operations. Depending on stump density per acre, and the volume of spray required for spot treatment, costs ranged from £8-£15 per acre. Basal bark spraying of standing growth on the other hand has proved disappointing in practice, owing to the labour required for preparation and application, and the large volumes of spray required. In most cases, costs exceeded £20 per acre for full treatment. However, partial treatment in strips, groups, or to individual trees, can be applied more cheaply. It is now clear that overall foliage spraying and cut stump treatment are the techniques most likely to prove of general practical use.

Recent experiments on the treatment of cut stumps included tests of sulphamic acid as an alternative to its salt ammonium sulphamate. Tests of these two compounds, applied in aqueous solution at rates equivalent to 1, 3, and 6 lb. of the ammonium salt per gallon, showed that although the salt was slightly superior in some cases, there was generally little to choose between them. At the equivalent of 3 lb. of ammonium salt per gallon, both compounds gave 80%-100% control of stumps of hazel, birch, rhododendron, hawthorn and oak. Sycamore and willow were relatively resistant to this treatment, but good control was achieved with 2,4,5-T ester at 15 lb. (acid) per 100 gallons oil. Ash stumps were found to be resistant to all treatments, the highest kill achieved being 50% with 2,4,5-T.

In practice, 2,4,5-T in oil remains the most useful stump treatment for most coppicing species. However, inconsistent results in practice have suggested that variations in the precise technique of application may be important. This was investigated in 1957/58, in trials to bring out the effects of directing treatments at different parts of the stump surfaces.

In August 1957, 2,4,5-T ester at 15 lb. (acid) per 100 gallons oil was applied at several positions on fresh stumps of oak, birch, and sycamore, with the results shown in Table 15.

Results suggest that the bark and sides of the stumps are the most vulnerable points for treatment. In most operations sprays have been directed at the cut surface, but future recommendations should be amended to stress that the spray target should be the *periphery* of the cut surface, and the bark of the stump to the ground line. Control of stumps by soil injection with herbicides as a means of reducing the amount of chemicals required has also been examined. Oil solutions of 2,4,5-T were injected under pressure, in 1 or 2 shots of 10 mls. each, placed a few inches from the stump and close to main lateral roots. Injection proved a quick and economic method of application, but for sycamore, birch and hazel the stump control achieved was poor compared with conventional spray treatment.

Table 15

Control of Cut Stumps with 2,4,5-T:
The Influence of Position of Application

Mean No. Shoots per Stump (12 months after treatment)

Position of Treatment	Oak	Birch	Sycamore
1. Overall	0	0	0
2. Cut surface	44	5	1
3. Bark	0	0	0
4. Stump collar (ground line only)	17	8	2

For treatment of large standing growth, basal bark spraying can be effective, but may be inconvenient and costly to apply where a large number of stems per acre are to be treated. Because of this it was decided to test soil treatment with herbicides acting through root absorption as a means of controlling hardwood scrub. In the first trial, monuron was applied beneath mixed scrub at 10 and 20 lb. per acre to 5 ft. wide strips at 15 ft. intervals, with the object of bringing the herbicide within reach of the root systems of all the standing growth, without sterilising the ground between the treated strips. Results one year after application have been quite striking, and 12-24 ft. high coppice of oak, ash, birch, and willow has been killed or severely checked. However, the lateral spread into the intervening untreated strips has been negligible. This is disappointing as it was thought that the technique might provide a means of controlling the scrub overwood in the adjacent untreated strips, so facilitating underplanting without the risk of herbicide residues.

Summer foliage spraying of *Calluna* with 2,4-D ester at 5 lb. (acid) in 50 gallons water per acre has proved highly effective, and has been applied extensively in experiments during 1957 and 1958. Recent tests indicate that the cheaper triethanolamine 2,4-D formulation may be equally effective at similar rates.

The treatment has been successfully applied for *Calluna* control prior to planting. Applied after planting there is some risk of damage to very young pine and spruce, but using directed sprays successful control has been achieved without crop injury in a variety of conifer species. The crop growth improvement following *Calluna* eradication has been striking at several forests. One of the largest effects has been a greatly enhanced crop response to added fertilizer where the *Calluna* has been controlled.

Investigations were also continued on the control of gorse (*Ulex gallii* and *U. europaea*) where these species constitute a weeding problem in parts of Wales.

At Taliesin forest, 2,4,5-T has proved highly effective for control of *U. gàllii* prior to planting. 2,4-D and 2,4,5-T esters were each tested at 5 lb. (acid) in 50 gallons of oil or water per acre in June. Results have shown that materials applied in water were most effective. Oil resulted in a very rapid superficial kill of leaves and shoots, which may have interfered with trans-location of the herbicide. Butyl iso-butyl 2,4,5-T in water was outstanding, controlling all gorse, young *Calluna*, and bedstraw, leaving a clear grass sward. 2,4-D ester effectively controlled *Calluna* and *Vaccinium*, but left the gorse relatively unharmed. Sprayed plots have now been planted with Sitka spruce to observe effects of crop growth. These trials have now been extended to examine dates and rates of application in more detail. Present indications are that good control of small gorse can be obtained with 2,4,5-T ester at 3-4 lb. (acid) per acre, applied as an overall spray in May-July.

There is little new to report on *Rhododendron* control, cut stump treatment with ammonium sulphamate remaining the only fully effective treatment known. However, at one forest in 1958 large-scale foliage spraying of regeneration on cut stools with 5 lb. 2,4,5-T per acre has proved quite successful. As noted in previous reports this treatment is unlikely to give a complete kill of stumps, but the severe setback to growth will probably be sufficient to reduce subsequent weeding costs considerably.

Miscellaneous

Gibberellic Acid for Stimulation of Growth of Seedlings and Transplants

Preliminary trials in 1957 with gibberellic acid, applied at 0.01% as an overall aqueous spray, and at 1% in lanolin paste as a shoot smear, showed promising shoot growth responses on beech and *Nothofagus* seedlings. These treatments were repeated in further trials on potted seedlings in 1958, and broadly confirm the earlier results by species as follows:

(i) *Large Response:*—beech—60-150% increased shoot growth with lanolin smear. *Nothofagus*—50% shoot increase.

(ii) *Small Response*—Lawson cypress, *Tsuga heterophylla*, and Douglas fir showed small, less than 10%, increases in shoot growth with treatment.

(iii) *No Response*—Scots pine, Norway spruce, Sitka spruce, *Abies grandis*, *Thuja plicata*, oak, and ash.

1% gibberellic acid in lanolin, applied as a smear to a 2-inch length of the leading shoots, was the most generally effective treatment. Incision of the shoots prior to smearing in March or June, 1958 proved to have no advantage over smearing of uninjured shoots.

The growth response in species such as beech consists almost entirely of increased shoot elongation, and no significant effects on stem diameter or root growth were observed. Also, recent observations on the seedlings treated in 1957 show that the growth effects do not continue during the season following treatment. Also, in 1958, tests were made on poplars using 1% and 3% gibberellic acid in lanolin, applied as a shoot smear in March and June. Treatment of cuttings of *Populus eugenii*, *P. robusta*, *P. tacamahaca* × *trichocarpa* 32, rooted cuttings of *P. gelrica*, and root suckers of *P. tremuloides*, failed to show any significant growth effects at the end of the first season.

Fire Retardants

Preliminary field tests with sodium calcium borate, and mono-ammonium phosphate, for fire-proofing low shrubby and grass vegetation, gave promising results in 1957. A 40% suspension of sodium calcium borate proved highly effective when applied as a spray to narrow strips of vegetation ahead of ground fires in *Molinia* and heather. The borate suspension is a thick slurry which is highly abrasive to conventional spraying and pumping equipment. This, together with the need for a spray pressure of 75-100 lb. per square inch, necessitates special equipment for practical scale application. This equipment has now been developed as a conversion of a standard 200-gallon water trailer. Fitted with pump and spraying equipment, such a trailer can be used to treat ½-1 mile of 3 ft. wide strip at a speed of 3-4 miles per hour, at one filling.

Mono-ammonium phosphate also shows promise, and trials are proceeding to test its use as a dry powder and in solution. Large-scale trials to establish costs and practicability will be carried out this season. On present evidence, chemical fire retardants would appear to be of considerable potential tactical value in forest fire control. In fire fighting, establishment of fireproofed strips should permit more efficient deployment and concentration of available water supplies and manpower at critical points. Similarly, counter-firing and controlled burning operations could be made much safer.

Chemical Methods of Pruning

In 1958, initial trials were started to test the use of herbicides for killing off small unwanted branches and epicormic shoots on oak and poplar. Continental evidence indicates that 2,4,5-T ester emulsions, applied as a summer foliage spray, are effective, the technique being cheaper and less likely to stimulate fresh epicormic growth than manual pruning.

Preliminary trials were carried out in August 1958, using amyl 2,4,5-T at 0.1% and 0.2%, applied as a directed foliage spray to epicormic shoots of oak, and black and balsam poplars. Assessment of shoots in October 1958 showed little difference between concentrations, but appreciable differences between species. Thus, poplar showed extensive death of sprayed shoots, but in the case of oak few shoots were killed back for more than half their length from the tips. It is too early to pronounce on these results, as much depends on the extent of shoot abscission and fresh epicormic growth this summer. If successful, spraying could be a great saving in manpower, the recent tests indicating that the manpower requirement is less than 10% that required for manual pruning.

SILVICULTURAL INVESTIGATIONS IN THE FOREST

(B) SCOTLAND AND NORTH ENGLAND

By M. V. EDWARDS, G. G. STEWART and D. W. HENMAN

Replanting Areas of Recently Cleared Conifers 230.9

The background to the problems of replanting hill areas was given in the 1958 *Report*. In brief, the main points of enquiry concern the growth of different species in the second rotation, and the effects of ground preparation where this is essential for the establishment of the first crop. Four experiments, making a total of nine to date, have been established during the year to compare the growth of ten species on cleared areas. Three of these experiments are in Scottish Border Forests on sites which before afforestation were believed to be dominated by *Molinia* and which are typical of very large areas which have been planted; the fourth experiment is in Port Clair Forest, in the Great Glen of Inverness-shire.

In two of these experiments, further trials of cultivation were made, using a tine plough hydraulically mounted on a crawler tractor. Although there was no peat at these sites, the tractor and plough had considerable difficulty in working. Stumps, if caught squarely by the plough, were often pulled right out of the ground and frequently the plough had to be raised to free it of these stumps. The ploughing certainly produced adequate cultivation, but with the disturbance of most of the stumps—some turned on end and some completely overturned; the drainage was disrupted and many deep water-filled pockets were left. Planting was not easy and suitable planting spots were not readily found. These factors, taken together with the severe strain imposed on the tractor and plough, confirmed last year's finding that if re-cultivation is found to be very beneficial (and the experiments are designed to test the necessity for cultivation) a different type of machine will need to be designed for general practice.

One result has become clear from the previous year's replanting trials; the need for very much larger plants than are generally used in first afforestation of bare ground. After cultivation, the invasion of grasses on the mineral soils has been fast and complete, and plants of a size which would be normal for the planting of plough ridges were overgrown and required much extensive weeding to save them. This is an obvious but important observational result.

In this year's work, as in last year's, there remains the problem of the control of deer which are normally excluded by high and costly deer-proof fences. Efforts to find more economic deer protection methods have been undertaken separately and this matter is dealt with later in this *Report*. (See Page 46.)

Afforestation Problems

Peatland 232.11:233

In the larger of the Border Forests, where the principal soil type is clay overlaid with peat from a few inches to twelve inches deep, and where the vegetation is dominated by *Molinia*, the main afforestation species has been Sitka spruce, with Norway spruce as the second most widely-used species. For many years other possible afforestation species have been sought as "second strings", and a trial of sixteen different species planted pure in half-acre plots was laid down at the Forest of Ae, Dumfriesshire, during the year. (Some smaller plots covering 23 species, including hardwoods, were also planted.) This experiment completes a series of three, the other two of which are at Glentrool Forest, Kirkcudbrightshire, and Kielder Forest, Northumberland, planted between 1951 and 1954. Two more large blocks of pure lodgepole pine were established, with the co-operation of Conservators, to provide areas for future experimentation in the later stages of growth on deep peat. These blocks, and the four planted last year, are all on land not normally planted but where the establishment of tree crops is now possible although still in the experimental stage.

Trial Plantations on other Limiting Sites 232.11:233:425

A further three trials were established at Hebden Royd Forest, Yorkshire, which is in a part of the Pennines considered to suffer from a heavily polluted atmosphere. These trials are situated on one side of a valley which runs north-east—south-west. Two are on a fairly broad shelf, one on *Molinia* peat and one on mineral soil with a grass/rush vegetation. Both these plots are exposed to the south-west, and the sites are not dissimilar from those planted in 1957 also in a part of Hebden Royd Forest, but farther to the north, near Withens Clough Reservoir. The third site is on a steep bank at the bottom of the valley, alongside two small pole-stage plantations with which the new trial will form an interesting comparison.

The 1958 *Report* mentioned an attempt to isolate the factors of infertile soil and exposure from that of atmospheric pollution, by planting lodgepole pine, Sitka spruce, sycamore and birch, in cardboard pots containing a good fertile soil, and later transferring the pots to the forest site; some plants in pots were inserted in the ground inside a lath shelter fence of about fifty per cent pore space. Controls were established at other forests in a clean atmosphere. At the end of the second year, the shoots and needles of lodgepole pine and Sitka spruce were much less discoloured inside the shelters than outside them at the two polluted sites. Shelter significantly increased growth of all species, but lodgepole pine was the only species to show better height growth when sheltered than when exposed, at all the sites.

Two further trials have been laid down this year, one at Hebden Royd Forest (polluted atmosphere) and one at the Forest of Ae (clean atmosphere). They have been designed on a larger scale to give more precise information; alternate lodgepole pine and Sitka spruce have been planted over an area of about one acre, in the middle of which a circular lath fence ninety feet in diameter and four feet high has been erected. The response to the shelter will be estimated from the growth of the plants at different distances from the circular shelter fence, both inside and outside the fence.

Manuring in the Forest 232.425.1:237.4

The results of a series of experiments comparing the use of triple superphosphate with ground mineral phosphate were given in Part III of the 1958 *Report*. The general conclusion was that half an ounce of triple superphosphate gave similar results, judged by the growth of young plants, to 1½ oz. of ground mineral phosphate, and that no damage was caused to the plants by the use of triple superphosphate. It was realised, however, that in this series of experiments the triple superphosphate had usually been applied some weeks after planting, and it is possible that it might cause damage to the plants if applied immediately after planting. Two experiments—one on an upland heath and one on a *Molinia* site—have now been established to compare times of application; these times range from the day of planting to thirty days after planting, and a wide range of species has been used.

Little manuring of pole-stage crops had been done in this country until very recently but some experiments were mentioned in the 1958 *Report* by R. F. Wood and G. D. Holmes (see also page 35). Another experiment in this series has been laid down this year at Durris Forest, Kincardineshire, in 25-year-old Quality Class III Norway spruce. The responses will be measured on a plot basis by basal area and top height, and on selected trees by using aluminium band vernier dendrometers for girth increment determination. The uptake of nutrients will also be estimated by needle analysis, which will be undertaken by the Macaulay Institute at Aberdeen.

At Culbin Forest, Moray and Nairnshire, there are certain areas where the crops have not developed satisfactorily. Some of these areas are in tall heather growing on sand, and some are on gravel sites. On a heather site an experiment has been laid down to determine whether the checking of the trees is due to the presence of heather. On the gravel sites there is no heather and the check must be caused by other factors, for example, lack of moisture. The introduction of broad-leaved species or of nitrogen-fixing undercrops might be valuable on these sites, and attempts to raise broom and lupins have begun this year.

The investigations into the nutrient content of needles of different species of conifers, mentioned in the 1958 *Report*, have been continued by the Macaulay Institute. Preliminary results indicate that it may be possible to determine whether or not a checked crop will respond to a fertilizer dressing. At present there is no certain way of telling whether a checked crop will respond to draining, or to mulching, or to a fertilizer top dressing; so such a diagnostic technique would have most important practical implications.

Spacing 232.43

Many of the spacing experiments planted 24 years ago received their second thinning during the year, and the scheduled assessments were carried out. These experiments will be able to furnish comparisons of form, growth and yield between the various spacings, and between the different methods of thinning superimposed on the spacings.

Tending of Crops

Thinning 242

Following the establishment last year of an experiment comparing a heavy crown thinning in Norway spruce with a moderately heavy low thinning, it was decided to begin a larger experiment in Sitka spruce with the main emphasis on periodicity and quantity of thinnings. A suitable site has been found at Loch Eck Forest, Argyll, and a preliminary uniformity survey completed; the treatments will be applied later in the year.

Pruning 245.13

Pruned stems of Douglas fir and Norway and Sitka spruce from the experiments at Inverliever Forest, Argyll, which were largely destroyed by windblow in 1957, have been sawn up for examination of their internal structure. Acknowledgments are due to Capt. J. Maxwell Macdonald of Largie Estate for assistance in this work. Though it is too soon after pruning to make a detailed study of timber qualities (first pruning was done in 1938) the examination showed that no more ill effects have resulted from pruning vigorous live branches than from removing moribund or dead branches. It also confirmed that girth measurements taken over bark at time of pruning give a good measure of the diameter of the knotty core as exposed on converting the log. Most important, the examination revealed how small was the radial thickness of knot-free wood laid on during 19 years, relative to the diameter of the knotty cores, even though post-pruning growth of the trees averaged 6 rings per inch. In order to increase the ratio of clear timber to knotty core, pruning must be started at a much earlier age than was done at Inverliever, or is usually contemplated for pruning or brashing in forest practice. Only the largest of the straight trees in a crop should be considered for pruning, and this should be started at a maximum over-bark diameter, breast height, of four inches.

As a result of the attention focussed on knotty core size by this examination, and by pruning in spacing and thinning experiments, a trial was begun during the year in which pruning of a fifteen-year-old Douglas fir crop at Durris Forest, is controlled by the diameter growth of the trees, individual trees being pruned at short intervals to various upper stem diameters. The object is to obtain knotty cores of small and constant diameter, without reducing height or girth growth in the pruned trees.

Protection against Deer 451.2

There are few upland forests beyond the establishment stage which do not shelter deer. These deer, usually roe deer, do virtually no damage to established trees; it is only when planting is undertaken within the forest that they cause damage. In these circumstances their browsing can effectively prevent the regeneration of cleared areas. Deer can be excluded from these areas by erecting suitable fences, but these are so expensive that they can be used only in special cases. The prohibitive cost per acre of fencing small areas against deer has been a severe hindrance to the replanting of cleared areas, for example windblown patches.

Consequently it is obviously of great importance to find cheap methods of excluding deer at least temporarily, from newly replanted areas. With this object, a small trial was laid down in 1957, in co-operation with the Conservator, at Grizedale Forest, Lancashire. This compared the protection afforded by covering newly planted Norway spruce and western hemlock with a layer of branches, and laying ten feet wide strips of branches round the edges of a plot. It is believed that deer do not like walking through a tangled mat of branches; after the first year there had been more browsing damage in the unprotected controls than in the protected plots.

This year, three further experiments have been established at the Forest of Ae, Port Clair Forest, and Newcastleton Forest, Roxburghshire. The species planted were lodgepole pine and Sitka spruce, and in addition to the two protection treatments used at Grizedale, another treatment consisting of old sheep netting laid as a 10-foot wide strip round the area to be protected, was tried. The netting was raised about 6 in. from the ground using stumps and pegs.

Electric fencing against deer has been used in Europe for many years, and there have been a few recent trials in this country. At Inverliever Forest, Argyll, two experiments were established to test the effect of electric fencing as a means of protecting small cleared areas within the forest. Two wires were used, the one above the other at heights of 2 ft. and 4½ ft. from the ground, and the species protected were lodgepole pine and Sitka spruce. No damage has yet occurred in either protected treatments or controls.

PROVENANCE STUDIES

By R. F. WOOD, R. LINES, and J. R. ALDHOUS

Pinus nigra

A valuable characteristic of *Pinus nigra* (in the wide sense) is its degree of tolerance of atmospheric pollution, which is sufficient to make it worth cultivating in certain moderately polluted neighbourhoods where other conifers will fail. Unfortunately, many such sites, especially in the Pennines adjacent to Yorkshire and Lancashire industrial regions, are also elevated and exposed. Our standard variety of black pine, *P. nigra* var. *calabrica*, which has usually been obtained from Corsica, is prone to "die-back" if carried to climates too cool and moist. Such die-back usually occurs at the thicket stage in plantations, and is often associated with the leaf cast fungus *Brunchorstia*. Field surveys in the Pennines and other upland districts have located stands which have tolerated the adverse conditions with success, and there appears to be some encouragement to start provenance studies on this special aspect of black pine.

A collection of fourteen provenances has been obtained in order to follow up the evidence of the field survey. No attempt has been made to obtain provenances representative of the whole of the natural range of *P. nigra*; rather, nine provenances have been obtained outside of this range, from stands which, growing in northern Europe, had shown their ability to tolerate a substantial northerly shift in latitude. These include pine from the Forest Departments in Belgium and France. Seed from black pine, which has had several generations of natural selection in a northern and oceanic climate, may well prove more suitable for Britain than directly imported seed from a Mediterranean mountain climate.

Efforts were also made to obtain seed in Britain from stands of *P. nigra*, growing in smoke-polluted areas or in exposed conditions, but it was soon evident that under these conditions even moderate seed crops rarely occur.

After two years in the nursery, the tallest plants were those from the mixed collection from the 1st, 2nd and 3rd generation of Vilmorin's collection at Les Barres, France, and from Turkey, while the shortest were those from British stands. The provenance from the standard source of collection (Corsica) is of medium height. There were striking differences in the appearance of the first-year seedlings, those of true Corsican origin having markedly stiff and straight primary needles, while those of Austrian, Calabrian or Turkish provenances had curved needles. The needles developed in the second year, however, appeared to reverse the position and the Corsican provenance developed its characteristic twisted and curved needles, while those of the Austrian and Turkish provenances were stiff and straight.

This provenance collection will be planted out in spring, 1960, on sites under polluted conditions in the Pennines and South Wales and on sites elsewhere where "die-back" of Corsican pine has already occurred.

Lodgepole pine

By the kind invitation of the Forestry Division, a tour of stands of lodgepole pine in the Irish Republic was carried out by R. Lines in September, 1958. The prime object was to survey and assess the suitability for seed collection of a number of stands widely distributed over the Republic, but it provided a further opportunity to study the effect of provenance on the growth of lodgepole pine, following an earlier visit in 1955. Of particular interest was the discovery of stands planted in 1941 of Lulu Island, British Columbia, provenance; these provide a clue to the future growth of the very large areas planted in Scotland between 1950 and 1955 with this provenance of seed. The Irish stands of Lulu Island seed show much less vigorous growth than stands of similar age from Washington coast seed, but they have reasonable stem form and have so far proved to be healthy. One feature which especially distinguishes them is their early and prolific flowering and coning; however collections of seed from this freely-coning but inferior provenance should be avoided.

Some small samples of seed supplied by W. B. Critchfield of the University of California, in exchange for material from British provenance experiments, provided up to 20 plants each of 12 provenances ranging from Alaska to California, and from coastal sand dunes to 8,800 feet in the Rocky Mountains. The number of plants was insufficient for a replicated provenance experiment, but individual trees have been planted in demonstration areas near existing provenance trials in Scotland, at Bedgebury Pinetum, Kent, and a genetical collection in East Lothian. Specimens have also been supplied to the Royal Botanic Garden, Edinburgh, while others are included in the Forestry Commission genetical collection.

For planting on poor sites in our wetter climates, the superiority of coastal provenances of *P. contorta* over those from more continental regions in western North America has been satisfactorily established. But we have as yet insufficient evidence about provenance differences inside the coastal region, which is of considerable extent, and recent provenance studies in *Pinus contorta* have been aimed at remedying this defect.

A trial was sown at Fleet Nursery, Kirkcudbright, in 1957, in which seven coastal provenances of lodgepole pine, ranging from Vancouver Island, British Columbia, to southern Oregon, were compared with two provenances from the Cascade Mountains, Oregon, and a home-collected seed lot. It was observed that the Cascade Mountain provenances had much larger seed than the coastal ones. At the end of the first season there were only slight differences in height between the provenances, but by the end of the second season, the transplants of the Cascade Mountain provenances were significantly smaller than the coastal ones. It seems that the large seeds of the interior provenances enabled them to make good growth in the first year, but that subsequently they were unable to maintain such vigorous growth as the coastal provenances. So far there is no evidence from this experiment that the northern coastal provenances grow more slowly than those from further south; in fact, the tallest provenance at present is from Ladysmith, Vancouver Island.

The plants from this experiment have been planted at three sites in Scotland: Glentrool, Kirkcudbrightshire, on poor quality deep peat; the Forest of Deer, Aberdeenshire, on a rather better bog but in a climatic region less favourable to the growth of pines; and Borgie, Sutherland, where interior provenances have repeatedly failed.

A similar collection of provenances (but containing two more coastal and one more inland provenance) of lodgepole pine, which was planted on five sites in south-west England and Wales in spring 1958, has become well-established at all sites. Growth of all races in the first year was satisfactory. However the two inland races from the Cascade Mountains, Oregon, which were smaller when planted out, have made the least height growth at all sites. This result conforms with that reported above for these two provenances at Fleet Nursery. Both provenances differ from the others in having needles which are longer, greyer and broader than those of any of the coastal provenances. Critchfield (1957) notes that in natural stands, the width of needles of trees from the Sierra-Cascade Mountain ranges is greater than from all other sources. The observations on the two Cascade provenances mentioned above agree closely with Critchfield's observations.

100 plants of each of the twelve provenances planted in England and Wales were retained at Bramshill nursery for later replacements, should these become necessary. Flowering was observed on some of these plants in spring 1959, and a count was made of the number of trees of each race bearing male or female flowers, or both. Table 16 gives the results of this assessment.

Table 16

Percentage of Three-year-old Plants of Eleven Provenances of Lodgepole Pine Flowering at Elvetham Nursery, Bramshill, Hampshire

Provenance	F.C. Identity Number	Flowering			
		Male flowers only	Female flowers only	Male and Female flowers	1st year cones
Lulu Island, Lower Fraser River, British Columbia	52/343	17	8	4	—
Langley, Lower Fraser River, British Columbia	53/627	20	4	1	1
Ladysmith, Vancouver Island, British Columbia	56/658	—	—	—	—
Keyport, Puget Sound, Washington	56/656	3	1	—	—
Long Beach, West Coast, Washington	56/654	1	—	—	—
Newport, Oregon Coast	56/655 (31.0.5)	2	—	—	—
Tidewater, Oregon Coast	56/655 (32.0.5)	—	—	—	—
Florence, Oregon Coast	56/655 (41.0.5)	—	—	—	—
North Bend, Oregon Coast	56/655 (45.0.5)	—	—	—	—
Cascadia, Cascade Mts., Oregon	56/657	—	—	—	—
Oakridge, Cascade Mts., Oregon	56/651	1	—	—	—

It will be seen that both the provenances from Lower Fraser River, British Columbia, are particularly precocious in flowering, and that Langley differs little from Lulu Island in this respect. One or two plants of the other most northerly races were flowering, but none of them to the extent of the Lower Fraser River provenances. It has to be seen whether early flowering and poor subsequent behaviour are associated in the Langley provenance in the way they are in the Lulu Island provenance.

Plants from Shuswap Lake, British Columbia, the third inland provenance, were not included in this assessment, being a year younger than plants of the other provenances.

Japanese Larch

In the spring of 1957, Dr. Langner of the Institut für Forstgenetik at Schmalenbeck, Germany, kindly sent samples of seed from 25 different sources in Japan. He had selected the areas himself during a tour of Japan, and the seed collection was carried out under the supervision of Professor Iwakawa. Similar parcels of seed were supplied to seven other Continental countries, so that the same provenances will be tested over a wide geographical area. This seed was sown in an unreplicated trial at Tulliallan Heathland Nursery, Fife, and produced between 200 and 900 seedlings of each provenance at the end of the season. Speed of germination appeared to be correlated with seed weight, with the heaviest seed germinating first, but there were several exceptions. Unfortunately *Botrytis cinerea* attacked the seedbeds, especially those with heavy stocking and good height growth, and as a result, survival figures are possibly misleading.

The heights at the end of the first season ranged from 6.7 inches to 2.5 inches, both extremes coming from Nagano prefecture, which has been a major source of Forestry Commission seed over many years. Three provenances from Tochigi prefecture which lies to the north-east of Nagano all showed excellent height growth.

As the season progressed it became apparent that there were very sharp differences in the time of development of autumn colouration. These differences were also evident in the autumn of the second year, when an assessment confirmed that the provenances were turning yellow in the same order.

In general, the pattern of growth in the transplant lines followed that in the seedbed, though, perhaps due to the cold, wet summer, all provenances made rather poor height growth, particularly those from above 6,000 feet elevation, and those from the areas of low mean annual temperature. Best growth was made by the provenances from moderate elevations.

In the spring of 1959 these provenances were planted in fully replicated experiments at Fetteresso, Kincardineshire; Broxa, Yorkshire; and Ystwyth, Cardiganshire. The first two sites are upland heaths in areas of fairly low rainfall, while the last is an upland grass bracken site with a rather high rainfall.

Sitka spruce

While there is good evidence that our standard source of seed, the Queen Charlotte Islands, British Columbia, is a suitable provenance for general use in Britain, no really comprehensive provenance experiment in Sitka spruce has yet been laid down. To repair this omission a provenance collection designed to sample the major part of the range of Sitka spruce was made in 1957 and in the following year thirteen provenances were sown in replicated experiments at Benmore Nursery, Argyll, and at Fleet Nursery, and twelve provenances at Wareham Nursery, Dorset.

Included in this collection are four Alaskan provenances (three at Wareham), four from British Columbia and two each from Washington and Oregon. An additional provenance from a Sitka spruce stand in Jutland, Denmark, has also been included.

The northern provenances germinated earlier than the others at Fleet, but at Benmore there was little difference in the speed of germination. At the end of the season at all three nurseries the tallest provenances were more than double the height of the smallest, which were the Alaskan provenances. The two tallest provenances at both Benmore and Fleet were from southern Oregon and the Queen Charlotte Islands. At Wareham the three tallest provenances were from Queen Charlotte Islands, Vancouver Island and Forks, Washington.

One striking feature of this collection at all nurseries was the southern origins' continued growth for several weeks after the Alaskan provenances had formed terminal buds and ceased growth. No autumn frosts occurred until late October to early November, and only the Oregon provenances suffered any appreciable frost damage.

As mentioned in the *Report on Forest Research*, 1957 (p. 52) a comparison of an extreme northern provenance from Cordova, Alaska, with others from the Queen Charlotte Islands, and a home collection from Inverliever forest, Argyll, was commenced in 1956. The Alaskan provenance produced hardly any plants large enough to line out at the end of the season, so all provenances were left in the beds and lined out the following July. After a further year and a half in the transplant lines they were assessed and the results are shown in Table 17 below.

Table 17

Provenance Comparisons of three-year-old Sitka spruce transplants: Oct. 1958

	Mean height inches		
	Tulliallan	Inchnacardoch	Mean
55/3 Cordova	6.8	7.8	7.3
55/804 Inverliever	12.2	12.4	12.3
53/663 Queen Charlotte Islands	10.8	14.2	12.5
Standard error of the mean	0.3	0.5	—
Difference necessary for significance: 5%	1.0	1.6	—
1%	1.4	2.3	—

From this table it will be seen that there was little difference between the Queen Charlotte Islands provenance and that from Inverliever, but that both these were highly significantly taller than the Alaskan provenance.

It is expected that the more southerly provenances will continue to grow more rapidly than the Alaskan one under normal conditions, but in the extreme north of Scotland and in high exposed trial plantations it may be found that the northern provenance is hardier and remains healthy longer. To test this, the three provenances, together with two others which came from stands in West Norway (which were originally from Alaskan seed), have been planted at Watermeetings Forest, Lanarkshire, on the summit of a bleak hill at an elevation of 1,600 feet; at Naver Forest, Sutherland, and at Ratagan, Wester Ross.

Western hemlock

The provenance variation of western hemlock, *Tsuga heterophylla*, is largely unknown, yet it has a very wide natural range, similar to that of Sitka spruce on the coast but with a far greater extension inland. As the species becomes more widely used, the importance of a provenance investigation is obvious, and to meet this need a collection of sixteen provenances from north-west America and two from stands in the British Isles has been sown at Benmore, Fleet and Wareham nurseries. Of these sixteen provenances, one comes from Alaska, three from the mainland of British Columbia, two from the Queen Charlotte Islands, four from Vancouver Island, four from Washington and two from Oregon. They cover a latitudinal range of 14½° (equivalent to the range between the Shetland Islands and Bordeaux) and an elevational range from sea level to 4,000 feet.

Douglas fir

The collection of fourteen Washington and three Oregon provenances of Douglas fir seed, planted at four sites in England and Wales in 1954, was assessed for height as at the end of 1956 (i.e. at the end of the third growing season).

While it is still rather early to expect reliable evidence on rates of growth, some pattern of behaviour can now be discerned. The best growth has been found in Washington provenances—from just behind the Coast Mountains (Elma), and from the foothills of the Cascade Mountains (Darrington and Ashford). Provenances from the three extreme coastal regions in Washington (Lopez Island, San Juan Islands; Sequim, North coast; and Hoquiam, West Coast) have all grown rather slowly. The growth of provenances from Oregon is average to poor.

At Shouldham Forest, Norfolk, this collection of provenances has been established on two sites, one in a frost flat and one on an adjacent slope above the level of the worst frosts.

In early May, 1959, several severe radiation frosts occurred, temperatures of 21-23°F. being recorded on the frost flat on May 1st, 4th, 5th, and 6th. Trees on this site were assessed for frost damage on 19th May, and at the same time an assessment of flushing was carried out in the main experimental block. The results of these assessments are given in Table 18 opposite.

The seventeenth provenance, from Sweet Home, Oregon, was not represented in the frost site at Shouldham. On the main block at Shouldham, it was more advanced in flushing than the most advanced provenances (Vernonia and Enumclaw (High)) represented on both sites.

The most striking feature of the table is the relationship between region of origin and freedom from frost damage. Of the provenances from Washington, those from the Puget Sound and Central Dry Belt region were clearly most affected by frost, while those from the West Coast were relatively free from damage. There is also a broad link up between frost damage and date of flushing; as would be expected, the provenances which are late in flushing (those from the

West Coast in particular) being less affected by frost than the early flushing provenances.

The second striking feature brought out by the table is the complete lack of connection between height and frost damage. There is obviously no evidence that the taller races have yet got above the zone of worst frost.

The two provenances from Oregon on the frost site were among the most severely damaged.

Table 18

Provenance	Percentage of trees unaffected by frost	Score* for flushing	Rank for Height at 1956–frost site–Shouldham
Upper Santiam River, Cascade Mts., Oregon	3	3	4
Lopez Island, San Juan Straits, Washington	8	2	13
Castle Rock, Central Dry Belt, Washington	22	3	3
Slab Camp, Sequim North Coast, Washington	26	4	4
Tenino, Washington Central Dry Belt	29	2	9
Wind River, Cascade Mountains, Washington	31	4	11
Vernonia, Oregon Coast	32	1	14
Graham, Cascade Mts., Washington	33	3	14
Darrington, Cascade Mts., Washington	42	5	2
Enumclaw (High), Cascade Mts., Washington	43	1	10
Ashford, Cascade Mts., Washington	46	3	6
Louella, Puget Sound, Washington	50	6	6
Enumclaw (Low), Cascade Mts., Washington	52	4	8
Sappho, Forks, West Coast, Washington	60	8	16
Elma, West Coast, Washington	79	9	1
Hoquiam, West Coast, Washington	84	10	12

* In the table, a score of 1 indicates that more than half the trees in plots of the provenance were flushing; a score of 10 indicates that very few of the trees had started to flush.

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POPLARS AND ELMS

By J. JOBLING

I. POPLARS

Varietal Studies

Varietal Trial Plots

Twenty-two new plots were laid down at Gaywood Forest, Norfolk; Harling, Thetford Chase, Norfolk; Rogate Forest, Sussex; and at Wynyard Forest, County Durham. For the first time a number of unsuccessful plots were scrapped at several trial areas to allow the inclusion of newer, or potentially more promising clones. Assessments were carried out at three trial areas during the season, including volume assessments in fourteen plots at Quantock Forest, Somerset. Here, mid-way through the ninth season from planting, ten clones have reached a height of over 40 feet, of which two have attained a height of 50 feet or more. The most impressive clones are *Populus* 'Androscoggin', *P. trichocarpa* C.F., *P.* 'robusta PH', *P.* 'Oxford', *P.* 'robusta AE', *P.* 'Casale 214' and *P.* 'Casale 154'. A summary of the measurements for these clones is given in Table 19. Each clone is represented by 16 trees at a spacing of 18 feet × 18 feet (134 trees per acre) occupying an area of 0.119 acres.

Table 19

Poplar Trial Plots: Quantock Forest, Somerset

Height, girth and volume at 8½ years

Clone	Average height of crop ft.	Average girth of crop ins.	Basal area per acre sq. ft.	Form factor	Volume per acre O.B. cu. ft.	Mean annual Volume increment cu. ft. p.a.
Androscoggin	62	29.5	50.3	0.397	1240	137.8
trichocarpa C.F.	46	27.5	44.4	0.376	769	85.2
Oxford	49	26.0	39.2	0.388	746	82.9
robusta PH	50	25.5	37.3	0.392	731	81.2
Casale 214	47	26.5	37.9	0.392	699	77.7
Casale 154	46	26.5	40.9	0.360	678	75.3
robusta AE	47	24.5	34.8	0.394	644	71.6

Varietal Collection

The collection of clones showed a net increase of 16, to a total of 373. Some of the latest introductions are of botanical interest only and have been obtained for inclusion in the Populetum, which now contains 243 clones, an increase of 32 over the previous year.

Silvicultural Experiments

Age and Type of Planting Stock

No new experiments were laid down, but recently-planted experiments were assessed at the end of the growing season. The results tend to confirm that unrooted sets generally are more difficult to establish than rooted plants, particularly on difficult ground, and that one-year sets are considerably less satisfactory than two-year sets. Their health is usually poor for one season and height growth may be very slow for two seasons. Survival during the first year is often in the balance, even with the best cultural measures.

Planting Treatments

Further experiments have been laid down to investigate the use of herbicides as a means of eliminating weed growth, and especially grasses, around the young trees. The effects of herbicide treatments are compared with those of mulches of cut vegetation, bark peelings and various other materials. (Herbicides are discussed more fully under "Silvicultural Investigations in the Forest"). A number of artificial mulches have been tested, and of these only black polythene appears sufficiently durable to suppress vegetation for more than one season. Vegetable parchment is the least durable of the materials tested, breaking up after only eight weeks. "Sisalkraft" paper showed signs of serious deterioration after about the twentieth week from application.

Experiments planted at Creran Forest, Argyll and Gaywood Forest, Norfolk in 1957 indicate that mulches of cut vegetation or straw are more beneficial to the health and early height growth of poplar than mulches of bark peelings or used fertilizer bags laid flat around the trees. Health, as indicated by leaf size and colour, is considerably improved, though the difference in height growth is not pronounced. However, trees receiving a mulch of bark peelings or fertilizer bags are appreciably healthier and more vigorous than trees which receive no treatment, and both materials may have a use on sites where there is insufficient vegetation to provide a satisfactory mulch, or where straw is not available. The experiments will need to be observed for a further period before recommendations can be made. A report has been prepared for publication as Forest Record No. 43. *Establishment Methods for Poplar*, which summarises the results of earlier work carried out on planting treatments.

Methods of Planting

No new work has been undertaken. The existing experiments are satisfactorily informative and confirm that trees planted in holes prepared by a post-hole borer or other types of auger behave as well as trees planted in hand-dug pits. Of three experiments laid down between 1955 and 1957, to investigate the use of explosives to prepare planting holes, two have given informative data. At Gaywood Forest, after two years, trees planted in holes prepared by exploding 4.0 oz. of gelignite are appreciably taller than trees planted in holes prepared by 1.6 oz. of gelignite, which in turn are taller than trees planted in hand-dug pits. A similar experiment at Alice Holt Forest has been in progress for four years, and here the current differences in total height are more pronounced, though early differences were not significant, as will be seen from Table 20.

This experiment is sited on a heavy clay soil where establishment of poplar is normally difficult. The result of blasting was to shatter the sides and considerably disturb the bottom of the pit. It is thought that this action has facilitated more vigorous root development and easier penetration than would be the case with hand-dug pits. 1.6 ounces of gelignite caused holes approximating in size to normal pits, that is 18 ins. $\times$ 18 ins. square and 15-18 ins. deep, while the larger quantities of explosive caused holes often 3 feet across and about 2 feet deep.

Table 20

Use of Explosives in Poplar Planting: Alice Holt Forest

Height of trees at end of each of first four seasons

Treatment	Mean Height in inches of 1/10 ft. class			
	1955	1956	1957	1958
Hand-dug pits	46.48	53.19	65.33	79.75
1.6 oz. Polar Ammon Gelignite	46.73	57.41	68.61	82.42
4 oz. Polar Ammon Gelignite	47.29	63.55	75.94	92.85
5.6 oz. Polar Ammon Gelignite	47.06	63.19	78.02	95.82
Standard Error	.979	1.181	1.403	1.208

Spacing in Plantations

Planting of an experiment started in 1958 at Chepstow Forest was completed. This is designed to compare the yield of pulp-wood from poplar when grown at close spacings. The spacings used are 7 feet × 7 feet, 11 feet × 11 feet and 15 feet × 15 feet, and the clone used is *P. tacamahaca* × *trichocarpa* 32, a particularly narrow crowned type.

Use of a Forest Tree species as an Understorey in Poplar Plantations

No new experiments have been started. Work has been confined to the establishment of an understorey of *Thuja plicata* at Gaywood Forest, Norfolk and of *Alnus glutinosa* at Mildenhall Woods, Suffolk.

Nursery Experiments

Weed Control in Transplant Beds

Work continued on the control of weed growth in nursery beds by applications of pentachlorphenol (P.C.P.), 'Vapourising oil' and Monuron during the growing season. Details of treatments are given under "Nursery Investigations", page 31. The last named material appeared to give the best control without damage to the young poplar.

Propagation of Summerwood Cuttings

In an experiment carried out in the mist propagation frame at Alice Holt, eight clones of poplar—namely *P. tremula* M, *P. tremuloides* H, *P. canescens* BS, *P. canescens* G, *P. canescens* S, *P. canescens* W, *P. grandidentata* × *tomentosa* S and *P. deltoides* 'angulata R'—were successfully rooted from softwood cuttings. It was found that *canescens* BS, C, S and W rooted relatively easily (75-100% success) while the remaining four clones rooted less easily (50-75% success). In general the best time for insertion for the number of cuttings rooted, survival and height growth, was the period end of May-early June. Most cuttings, which were four to five inches long, had rooted within three weeks of insertion. No growth substances were used, but it is likely that Seradix 1 will assist the rooting of more difficult clones, that is those which cannot be rooted from hardwood cuttings. *P. tremula* M, *P. tremuloides* H, *P. grandidentata* × *tomentosa* S and

P. deltoides 'angulata R' are examples of this type. Two rooting media were compared in the experiment, 50% fine sand, 50% sorbex peat; and 25% fine sand, 25% coarse sand, 50% sorbex peat. No significant differences were observed in the number of cuttings rooted, but in practice the fine sand-peat mixture is preferable.

Distribution of Cuttings

Between December 1958 and March 1959 cuttings of eight standard varieties were disposed of as shown in Table 21.

Table 21

Disposal of Poplar Cuttings: Forest Year, 1959

Destination	P. eugenei	P. gelrica	P. laevigiata	P. robusta	P. serotina	P. tacam. × tricho. 32	P. tacam. × tricho. 37	P. berolinensis
Forestry Commission	1,780	1,400	3,617	2,405	3,038	227	305	17
Private Estates	448	448	348	1,898	148	447	460	98
Trade Nurseries....	5,300	4,000	50	2,900	7,300	756	856	—
Dept. of Lands, Irish Republic	—	1,000	—	800	—	—	3,000	—
Total	7,528	6,848	4,015	8,003	10,486	1,430	4,621	115

In all 43,046 cuttings were distributed during the season. In addition some 500 cuttings of the standard varieties were despatched to the Forest Research Institute, Dehra Dun, India and the Bureau of Forestry, Seoul, Korea, and over 2,000 cuttings of non-standard varieties were sent to research workers abroad, to Canada, Germany, Holland, Hungary, India and New Zealand, in addition to a number of Institutes and interested growers in this country.

Bacterial Canker Investigation

"Long cuttings" of 210 clones were planted during the winter at Fen Row Nursery, Rendlesham Forest, Suffolk, for routine tests, preparatory to inoculation with bacterial slime during the late spring of 1959. Each clone was usually represented by ten cuttings. In addition six clones of known resistance or susceptibility to bacterial canker were planted in greater quantity, and the same clones sent to the Phytopathologisch Laboratorium "Willie Commelin Scholten", Baarn, Holland. These will be used to compare methods of inoculation of bacterial slime, and methods of assessment of degree of infection used in the two countries. A similar trial will be undertaken in Holland.

As in previous years, trees of highly canker-susceptible clones were planted at the major trial areas with the intention of establishing at each site a source of bacterial infection. The trees are inoculated in the spring after planting.

II. ELMS

Work in the field has been confined mainly to an initial survey of sources of potential good timber trees and of trees of silvicultural interest. Various estates have been visited in this connection and discussions have taken place with representatives of the timber trade. As a result material for propagation has been collected from a number of trees, and others have been noted for further inspection. Material has also been obtained from a few trees reported by Ir. H. M. Heybroek, Phytopath. Laboratorium "Willie Commelin Scholten", Baarn, Holland, to show signs of resistance to Elm Disease on inoculation. One of these, said to be a form of *U. carpinifolia*, is a particularly well grown specimen and worthy of trial.

The timber of elm is used mainly in the production of furniture, of coffin boards and in dock constructional work. For furniture and coffin boards straight-grained timber is used whenever possible, and the demand greatly exceeds the supply. The only elm which invariably gives this high quality timber is named by the trade "Dutch" elm. It is not yet certain, however, that this can be referred in all cases to *U. hollandica* var. *hollandica.* It is anticipated, therefore, that the next stage of the survey will be devoted partly to a more critical examination of so-called "Dutch" elm. To supplement supplies, the furniture and coffin board manufacturers use mainly English elm, *U. procera.* This does not normally give a straight-grained, easily worked timber, and only a short length of the butt can be used. Trees grown in woodland conditions are sometimes preferred, having a greater length of usable timber. It is likely that quality varies considerably, and there are indications that it is most closely related to soil type. This aspect is being investigated. It has not been ascertained whether English elm is really preferred next to so-called "Dutch" elm on its own merits, as its frequent usage is due to its widespread distribution and availability in large sizes.

In the nursery, an experiment was carried out in a mist propagation frame, on the rooting of summerwood cuttings. Twelve clones were used and cuttings, four to five inches long, were inserted at four times during the season. In general the best time of insertion was the last two weeks of June, although some clones were successfully rooted by insertion during July. Not all clones behaved similarly; some rooted easily while others were relatively difficult to root. The use of Seradix 1 gave very variable results and, although not increasing total rooting, it tended to improve the speed of rooting of certain clones. Two rooting media were compared—50% fine sand, 50% Sorbex peat, and 25% fine sand, 25% coarse sand, 50% Sorbex peat—but no direct relationship with rooting could be established. In general all cuttings which were able to root had done so by the eighth week from insertion. There appeared to be no connection between rooting capacity and the source from which a given clone was obtained.

FOREST ECOLOGY

By J. M. B. BROWN

Ecology of Corsican pine

During the year several fresh reports were received of more or less serious dieback on upland sites, while other cases were encountered in the course of systematic observations on the performance of this tree in Britain. Among the interesting features recorded were a serious recent outbreak on some relatively young (less than 10-year-old) trees at 1,550 ft. in part of Kerry Forest, Shropshire, and the evidence of very similar symptoms on mountain pine and Scots pine at over 1,000 ft. in Clashindarroch Forest, Aberdeenshire, and on mountain pine and Austrian pine in Langdale Forest, North-east Yorkshire. Diseased Corsican pine occurs in both these localities.

As to the first point, whereas outbreaks of dieback in Corsican pine are normally an occurrence of plantations about twelve to thirty years old, the few certain instances of serious disease in plantations under ten years old are on sites where environmental conditions, in terms of latitude and altitude, are very far removed from the optimum. These cases may provisionally be interpreted as early incidence of disease on trees of abnormally low resistance. The development of disease in these young plantations will be kept under close observation during the next few years, with particular reference to the changes in stand structure and the occurrence of pathogenic fungi.

Disease in other pines, involving the dieback of twigs and commonly associated with the fungus *Brunchorstia destruens*, has been reported previously (Boudru, Leven, Waldie). The Corsican pine has no monopoly of this disease, however caused: but it is the most susceptible of the pines which are, or used to be, planted on upland sites. It is important that other pines be kept under observation from this point of view, both in their own interest and insofar as the evidence they provide may contribute to a fuller understanding of the general problem.

Some consideration has been given to the provenance of Corsican pine used in Forestry Commission plantations made since 1923: there are no records for earlier years, and only scanty records prior to 1932. Apart from small purchases or gifts of *Pinus nigra* seed from Italy, Cyprus, Austria, Spain or France, yielding plants which have mostly been used in experimental work, nearly all the seed has come from Corsica, formerly directly from local merchants in the island, latterly through the agency of an English firm. The rest has been collected in the older British plantations, mostly of unrecorded origin. In Corsica, the locality data occasionally supplied with the larger consignments of seed show for the stands contributing cones an altitudinal range of over 1,500 feet (from 900-1,400 metres or 2,700 to 4,200 feet above sea level, approx.); and it appeared likely that this considerable range might have a bearing on the incidence of disease on upland sites in Britain. So far there is no clear evidence of this: several instances of disease have been recorded in stands derived from seed purporting to come from 4,000 ft. and over. The possibility of obtaining greater success on upland sites with some extra-Corsican provenance is under consideration, but in view of the occurrence of disease on Austrian, mountain and Scots pines, the outlook is not bright. There are other aspects of the study of provenance in Corsican pine—for example the performance of the so-called "Ursuline" lots which entered the country between 1927 and 1937—and these are not being neglected.

In many of the plantations of Corsican pine on marginal sites there is evidence of a relationship between the prevalence of disease and features of local topography and stand structure. In most cases, conditions of air stagnation appear to favour early onset and rapid spread, and it is sometimes possible to relate the occurrence of patches of diseased trees within a stand, or the distribution of disease on the tree, to such conditions. There are, however, some cases of dieback on moderately steep and presumably well-drained valley slopes. Evidence is gradually accumulating that south and west aspects are more favourable to the Corsican pine in Britain than are north and east aspects: this may be because south and west aspects are on the whole warmer; or because they are in some degree protected in periods of severe air frost; or because they are generally better ventilated. Until much more is known about the course of outbreaks of disease and the influence of relief on climatic factors in hill lands, it will be difficult to formulate any satisfactory hypothesis linking disease and topographic features. There is no evidence that exposure to the prevalent winds is in any way detrimental to the health of Corsican pine on marginal sites, though the rate of growth may be affected by severe exposure.

In connection with these general studies of Corsican pine performance, in relation to provenance and to topographic and other locality factors, a visit was paid in June 1958 to some Corsican mountain forests, where local officers of the French Forest Service courteously provided information and guidance. Some of the woods which regularly supply cones for Britain were inspected; the general pattern of forest vegetation, particlarly the manner in which the distribution of maritime pine, Corsican pine and beech are affected by topographic and other factors, was examined; and examples of the granitic soils on which the best pine growth is found were fully described. Meteorological data, including rainfall and maximum and minimum air (screen) temperatures, maintained since May 1954 in a clearing in the heart of the Forêt de Valdo-niello, were made full use of, and have provided material for a preliminary comparison with data from British climatic stations, both lowland and upland.

Soil Surveys in Forests

Following the work in Tintern and Chepstow Forests (Monmouthshire), there has been close co-operation with the Working Plans Officer, the Pathologist and the Conservator of Forests in arrangements for a soil survey of Thetford Chase, where the prevalence of outbreaks of *Fomes annosus*, the measures being taken to gain a more even distribution of age-classes in the forest, and the desire to extend the range of species, have emphasised the need for more information about soil variations and the properties of the main soil types. As a result of negotiations with the Head of the Soil Survey, a Surveyor based on Cambridge is engaged on reconnaissance in Thetford Chase and the adjoining agricultural land and heath. He will be responsible for the soil map, but will keep in close touch with the Research Station and the local forest staff during the conduct of the survey.

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FOREST SOILS

By Dr. W. H. HINSON

Routine soil analysis has been carried out at the request of other sections, but as in previous years by far the largest assignment has been for analysis for the major nutrient content of samples of pine and spruce needles from the forest manuring trials conducted by the Silviculturist. Improvements have been made in the laboratory sampling procedure and expression of results, which should reduce the variation between sample trees, increase precision and facilitate the interpretation of the results. Now that these trials have been extended into pole-stage crops with closed canopy, the normal collection of material for foliar analysis from the top whorl of laterals has presented serious practical difficulties in the case of Sitka spruce. Accordingly an investigation is in progress of the distribution of nutrients in foliage from all parts of the crown of this species. It is hoped that it will be possible to define a more practical field procedure for sampling, and throw some light on the rationality of sampling prescriptions for foliar analysis of conifers generally.

The laboratory work on forms of fertilizers in relation to cation exchange properties of forest soils, referred to in the 1958 *Report* has been concluded, but field work is continuing. The effect of dressings of certain forms of soluble fertilizers on the available fraction, particularly ammonium nitrogen, show marked differences compared with neutral salts, even many months after application.

A set of colour slides exhibiting the foliar symptoms of major nutrient deficiencies in sand cultures of *Populus gelrica* have been taken, and the sand culture has now been discontinued.

Long Term Studies of the Nutrient Relations of Forest Crops and Forest Sites

The general programme was outlined in the 1958 *Report.*

Work on the question of sampling procedure is nearing completion. It is particularly fortunate that the effect of site factors and stand Quality Class, on the timber quality of Sitka spruce, is the subject of a current joint investigation with the Forest Products Research Laboratory at Princes Risborough. It has therefore been decided to concentrate the initial nutrient studies on Sitka spruce, and to adopt a common network of sites for both investigations. This effects some economy in field work and is advantageous from numerous points of view.

FOREST GENETICS

By J. D. MATTHEWS, A. F. MITCHELL and R. FAULKNER

General Programme of Improvement 165.3:232.311

During the year the work continued to develop along established lines. Progress can be reported in vegetative propagation by cuttings—good results having again been obtained with several species using the "mist" method of propagation. The first field trials of larch progenies derived from controlled pollinations were laid down at four sites in England, Scotland and Wales. Controlled crosses were again attempted on large trees of Douglas fir, and partial stem girdling was successfully used to increase flower production in seven-year-old graftings of beech.

Survey of Seed Sources 232.311.2

The object of this survey is to locate suitable seed sources for current planting programmes so that the practising forester may know where to obtain seed of the best of the existing varieties. The greater part of the survey work in 1958 was in the North-east England Conservancy and thirty-two additions were made to the Register of Seed Sources for England.

Table 22

The Selection, Registration and Propagation of Plus and Other Trees

Common Name	Latin Name	Selected and Registered	Propagated Vegetatively	Planted in Tree Banks
Scots pine	Pinus sylvestris	691	598	420
Corsican pine	P. nigra calabrica	87	62	46
Other pines	Pinus spp.	69	35	5
European larch	Larix decidua....	448	261	239
Japanese larch	Larix leptolepis	123	72	51
Other larches	Larix spp.	42	17	13
Douglas fir	Pseudotsuga taxifolia	431	269	201
Norway spruce	Picea abies	64	17	—
Sitka spruce	Picea sitchensis	140	25	—
Other spruces	Picea spp.	15	—	—
Silver firs	Abies spp.	50	—	—
Western hemlock	Tsuga heterophylla	35	9	—
Western red cedar	Thuja plicata	50	36	30
Other conifers	—	79	33	16
Total Conifer	—	2,324	1,434	1,021
Oak spp.	Quercus robur and Q. petraea	166	27	4
Beech	Fagus sylvatica	115	65	39
Sycamore	Acer pseudoplatanus....	25	2	—
Ash	Fraxinus excelsior	42	24	10
Birch spp.	Betula spp.	62	22	1
Other broadleaved species	—	16	7	—
Total Broadleaved	—	426	147	54
Grand Total	—	2,750	1,581	1,075

Testing the Registered Seed Sources 232.1

Advantage was taken of the good cone crop of 1956 to collect seed from ten registered seed sources of European larch, and from eight registered seed sources of Douglas fir. All these seed sources are located in Scotland, and the seed was sown and plants raised at Bush Nursery (Midlothian). The progeny were planted out during the spring of 1959, the European larch at one site in central Wales and three in Scotland; and the Douglas fir at one site in northern England

and two in Scotland. Another section of the Douglas fir trial will be planted in southern England in 1960. Those seed sources which yield progeny which are vigorous and well formed, on the majority of the sites on which they are tested, will eventually be registered as Elite or tested seed sources.

Selection of Plus Trees 165.62

The selection and propagation of outstanding phenotypes (plus trees) and other trees of more specialized interest (special trees) was continued. The total number of plus and special trees of all species which have been marked and recorded is now 2,750. Table 22 gives the position by species on the 31st March, 1959.

It will be seen that the pines, larches and Douglas fir make up just over two-thirds of the trees that have been selected and registered. The intention now is to select more spruces as a first step towards the improvement of this important group of species.

Just over half of the selected trees have been propagated by grafting, or by the rooting of cuttings, and just over one-third are now established in Tree Banks.

Formation of Tree Banks

The establishment of the National Collection of Plus and Special trees, mostly of two-needled pines, the larches, Douglas fir and beech, was continued during the year and a total of 1,075 clones have now been planted. The number of clones planted is given by species in Table 22, while Table 23 shows the location of each Tree Bank, and the area of ground allotted to each species as at 31st March, 1959.

Table 23

Location and Area in Acres of Tree Banks by Species

Location	Scots and Other Pines	Larches	Douglas fir	Beech	Total
Newton Nursery, Morayshire	8	½	7	—	15½
Bush Nursery, Midlothian	—	4	—	—	4
Alice Holt, Hampshire	1½	1	—	—	2½
Bradon Forest, Wiltshire	—	—	—	1	1
Rendlesham Nursery, Suffolk	1	—	—	—	1
Total	10½	5½	7	1	24

Vegetative Propagation 232.328

Grafting, the rooting of cuttings and layering were again used to raise clonal material for inclusion in tree banks, field trials and seed orchards. The final total of grafts attempted during the spring of 1958 was 12,727, and the total of successful grafts surviving to the spring of 1959 was 8,856, representing 682 parent trees. The overall success was seventy per cent, and the figures for the main propagation centres were: Alice Holt 3,246 grafts attempted and 56 per cent success; Grizedale 6,642 grafts attempted and 75 per cent success; and Bush Nursery 2,513 grafts attempted and 78 per cent success. The spring weather was unfavourable to outdoor grafting, as shown by the results at Grizedale where grafting under glass gave 84 per cent success but grafting outdoors 44 per cent success.

Just over 18,000 cuttings were inserted in the propagation frames at the Alice Holt, Grizedale, Bush and Kennington nurseries, most of these being clones of X *Cupressocyparis leylandii.* During the spring of 1959, 7,925 rooted cuttings, principally *Thuja plicata* and X *Cupressocyparis leylandii,* were distributed for planting in field trials and tree banks.

The success of outdoor grafting of larch in Britain is very dependent on the weather in March and April. The newly grafted scions often die in cold, dry, windy weather and some protection is obviously desirable. In a small trial at Bush Nursery in spring 1958, perforated and unperforated polythene bags were put over the scions and tied into position just below the graft union. The results have been most promising, both in raising the percentage success and increasing the growth of the scions when contrasted with the untreated controls. The method is now being tested in replicated trials involving European, Japanese larch and Douglas fir at the three main propagation centres.

In 1957 a "mist" propagation unit was installed in one of the larger, heated propagation frames at Alice Holt. The unit is of the type developed at the Natural Institute of Agricultural Engineering, in which an "electronic leaf" is used to control the supply of water, which reaches the cuttings as a fine mist. Cuttings of several Poplar and elm species, and of Leyland cypress, were inserted during the summer, and good success was obtained with all the clones. The results of the experiments with poplars and elms are further reported on pages 56 and 58.

A new propagation frame incorporating both mains-voltage soil warming and a "mist" unit, which includes means for gradually reducing the supply of water (i.e. "weaning" the rooted cuttings), was completed at Alice Holt during the spring of 1959. This will be used for elm and poplar clones which are difficult to root by conventional methods. The advantages of the "mist" method are three-fold. First, cuttings can be inserted early in the growing season when extension growth is very active; second, cuttings can be rooted quickly; third, the range of species which can be rooted from cuttings is greatly extended.

The series of experiments on the rooting of Leyland cypress (*X Cupressocyparis leylandii*) was completed during the year. The results of work in 1948-50 and 1953 were summarised in the *Research Reports* for 1951 and 1953. Now the knowledge gained from these and the 1957-58 series of experiments has been incorporated into general prescriptions for the rooting of cuttings of this valuable hybrid, cf. *Quarterly Journal of Forestry,* Vol. LIV, 2, 1960, pp. 127-140.

Testing the Plus Trees 232.1

The raising of the progeny derived from open pollination and controlled self and cross pollinations in the two-needled pines, larches, Douglas fir and beech was continued during the year.

The open-pollinated progenies of sixteen plus trees of Scots pine were planted at Devilla Forest (Fifeshire) and the larch and Douglas fir progenies derived from the controlled crossing programmes of 1956 were also planted-out in several field trials. The Douglas fir trial planted at Saltoun Forest (East Lothian) included twenty-five controlled crosses made on plus trees, five open-pollinated progenies, the progenies of eight Scottish seed sources, and four American provenances, thus providing a severe test for the progenies produced by controlled crosses. The larch progenies included intra-species crosses within European and Japanese larches, and also hybrids between these two species. These were planted out at four sites, two in England and one each in Scotland and Wales. Ninety-five progenies are now under test.

Some of the older plus trees of Douglas fir flowered in spring 1958, and a number of crosses were attempted on these trees at Dropmore Arboretum (Buckinghamshire). A pine crossing programme was also carried out in the Croxton Park Scots pine provenance trial, Thetford Forest (Norfolk). Here, intra-species crosses between several provenances of Scots pine, ranging from Sweden through to Italy, and the cross Scots pine × lodgepole pine were attempted. The cross Corsican pine × Scots pine was attempted at Alice Holt, using clones of grafted plants from plus trees of Corsican pine as the female parents, and several provenances of Scots pine as the male parents.

The Formation of Seed Orchards 165.4:232.31

Seed orchards of Scots pine, European larch, Douglas fir and beech are being formed both to produce seed and to provide a means of further improvement of these species. Seed orchards composed of clones of European and Japanese larch are also being planted to produce seed of the first generation hybrid *Larix × eurolepis*. A fresh departure this year was the formation of seed orchards for the production of second generation hybrid larch seed, and of the backcrosses: hybrid larch × Japanese larch, and hybrid larch × European larch. These seed orchards are composed of carefully selected first generation progenies raised from seed. Table 24 summarises the present position, and shows the area of seed orchards planted or in formation in various parts of Britain. Work is in progress at 19 sites totalling 205 acres.

Table 24

Area in Acres of Seed Orchards in Various Parts of Britain

Location (Region)	Scots and other pines	Larches	Douglas fir	Beech	Other species	Total
East and Central Scotland	14	9	7½	—	½	31
South-West Scotland	—	2	—	—	—	2
South-East Scotland	24	9	5	2	—	40
South-East England	8	12½	5	7	4	36½
West Midlands of England	—	13	—	—	—	13
East England	4	3	—	½	—	7½
North-West England	—	1	—	—	—	1
Total	50	49½	17½	9½	4½	131

Note: "Other species" include ash and western red cedar.

The Technique of Tree Breeding 165.7:232.311.3:232.311

The work which has been done during the past three years on the collection, ripening, extraction storage, testing and use of pollen is described by Mr. R. Worsley in an article in *Silvae Genetica*, Vol. VIII, No. 5, (1959). pp. 143-148.

The experience gained has been employed in designing five pollen extraction chambers, which will form part of the laboratory facilities at Alice Holt.

The relatively short period of hot, dry sunny weather during late June and early July, 1957, was evidently sufficient to stimulate flower bud formation in several clones of beech at Alice Holt and during April and May, 1958, observations were continued on the flowering of thirteen clones of beech produced in 1951 by grafting scions from adult trees onto juvenile rootstocks. The results of these observations may be summarised as follows:

(1). There is great variation between clones both in time of first flowering and the quantity of male and female flowers produced. One clone flowered in the third season after grafting; three have flowered from the fourth season; three have not yet flowered nine seasons after grafting. One clone of nine plants produced over 1,500 female flowers in 1958.

(2). Many flowers of both sexes are borne on "short shoots" situated in the lower and middle parts of the crown.

(3). The flowering of most grafts has tended to be biennial; one graft has produced a few flowers each year since 1954.

(4). Partial stem girdling applied in May 1957 resulted, with some exceptions, in increased production of flowers in 1958.

Some proposals for establishing seed orchards of beech have been derived from these studies. It appears that the size of the grafted plant is of some importance, both in determining the onset of flowering and the size of the seed crop. Within two fruitful clones in which a close comparison was possible, the larger graftings flowered first, and they also bore the largest crop of beech nuts. It follows that the scions should be encouraged to grow rapidly at first, in order to reach a large size quickly. One way of attaining this is to top-work well established rootstocks which are ten or more years old.

A new trial of methods of inducing flowering in Scots pine was established at Torrie Forest (Perthshire). The trees are rising six years of age, and the object of the experiment is to estimate the effect on both male and female flower production of single treatments and factorial combinations of root pruning, stem girdling, shoot pruning and applications of nitrogen, phosphorus and potassium. Co-operation continued with Mr. K. A. Longman of the Botany Department of Manchester University and Professor P. F. Wareing of the University College of Wales, Aberystwyth. They are both working on problems of tree physiology and their work is described on page 109.

Other Work

Technical advice was made available to the Scottish Forest Tree Seed Association and to the newly-formed Forest Tree Seed Association of England and Wales. The flow of enquiries from Forestry Commission and outside sources continued, some 92 enquiries being dealt with during the year.

FOREST PATHOLOGY

By T. R. PEACE

Work continued on various aspects of pathology, and the main lines are described below.

Lophodermium pinastri

This fungus caused serious loss of nursery stock in 1958. One Conservancy alone reported that, in consequence of its attacks, over two million diseased plants had had to be destroyed. Accordingly, a questionnaire was circulated among all the nurseries growing pine in North-East and North-West England Conservancies. The answers showed quite clearly that on seedlings the attacks were almost entirely confined to nurseries made in pinewoods. Nurseries surrounded by hardwoods, heathland, arable land or by conifers other than pine were virtually free of the disease. Visits to the nurseries confirmed the results of the questionnaire, and also revealed a distinct fall-off in infection intensity with distance from surrounding pine. Even in a small nursery only sixty yards across, infection was noticeably less in the centre than at the borders. It is hoped, therefore, that the incidence of the disease in nurseries can be greatly lessened by avoiding pine sowings in or near pinewoods.

Serious browning of plantation pine due to *Lophodermium* was also reported. It is thought that the wet summer of 1958, giving good infection conditions, favoured these attacks.

"Wareham Fungus"

Work continued on the fungus found on various species of pine in the Wareham area. Inoculations on potted plants were positive, confirming its pathogenicity. Comparison with American material showed that it differed in some characteristics from *Lecanosticta acicola*, the imperfect stage of *Scirrhia acicola*, the fungus causing "brown spot" on pine in America, but that it was apparently identical with *Dothistroma pini* Hulbary. The latter fungus has not been recorded previously in Britain, but has been reported causing browning of pine in several States in America. It is there much less damaging than the true "brown spot" fungus, the imperfect stage of which it closely resembles.

Ascochyta piniperda

Diseased seedlings and transplants sent for examination from six nurseries in North and East Scotland were found to be infected with *Ascochyta piniperda*, hitherto recorded only on Norway spruce. Spruce in the nurseries were not affected. The symptoms on the pine were browning of needles and death of shoots during the growing season, rather reminiscent of *Botrytis* attack. The typical black pycnidia of *Ascochyta* occurred abundantly on both needles and shoots. Inoculation trials of different races of lodgepole pine and other species were laid down.

Group Dying of Conifers (Rhizina inflata)

Little further work was done on this disease. Some new cases reported were visited and observational work was kept up. The number of new groups reported has diminished in the last year or two, presumably as the result of the prohibition of the lighting of fires for brewing tea, etc., during the thinning operations over large areas. Results of a fire lighting experiment showed that burnt areas arising from fires lit at any time of year could be colonised by *Rhizina*. This is an unexpected and important point in the control of the disease, since there might otherwise have been grounds for assuming that there would be a safe period at the time when the fungus was not fruiting.

Resin Bleeding of Douglas Fir

No further reports of this disease have been received. No work apart from the assessment of observational plots was carried out. This assessment has shown that in most areas the health of affected trees steadily deteriorated. Some deaths having occurred, but no cases of trees formerly assessed as healthy becoming diseased have occurred.

Keithia thujina on Thuja plicata

Nurseries involved in the rotational sowing scheme described in the report for last year were visited. Trials with fungicides were laid down. These mainly concern copper-containing fungicides and are a follow-up to previous work which showed that substances containing copper gave some control of the disease. The disease continues to cause heavy losses in nurseries throughout the country.

Melampsora pinitorqua

Infection of both aspen and pine was noted in the experimental test bed established at Alice Holt. Further additions of both aspen and pine species were made. Table 25 shows the species infected or not infected in 1958:—

Table 25

	Infected	Not infected
Pine species	P. sylvestris P. pinaster (severely)	P. resinosa P. radiata P. echinata P. nigra var. calabrica P. contorta P. muricata P. nigra P. densiflora
Aspen species	P. tremula P. tremula × tremuloides (very slightly)	P. tremuloides P. grandidentata (2 slightly infected with Melampsora rostrupii)

Thus, as in 1957, the American aspens showed no infection, though the cross between the susceptible European species, *P. tremula* and the American species, *P. tremuloides*, was slightly infected. It is dangerous, however, to assume resistance or susceptibility for a species from only one clone. In *P. tremula* for instance, which is represented by several clones, some clones showed infection while others did not. In addition the results in the "not affected" column are very tentative, since some of the species have not been under test long enough for one to be certain of their resistance.

Cronartium ribicola

Observations were kept up on the test-bed containing different varieties of currants and different species of five-needled pines at Alice Holt. Among the results from this is freedom from infection in clones of *P. strobus* obtained from America as selected resistant stock. *P. peuce* showed resistance, only one individual out of 22 being infected. Apart from these, infection is present on all the species of pine in the plot.

A trial was started at Bedgebury Forest of the effect of Acti-Dione in eradicating *Cronartium* cankers on the stems of *P. strobus*. Considerable success has been claimed in America in the use of this material. Such a technique would be extremely valuable in the preservation of arboretum pines.

Botrytis cinerea on Nursery Conifers

The results of spraying trials designed to protect a crop over a whole season proved disappointing. In *Sequoiadendran giganteum*, probably the species most requiring protection from *Botrytis*, no satisfactory control was achieved. Previous experiments had shown that satisfactory control could be obtained from short-term experiments using artificial infections. Some very small sowings of *S. giganteum* were made on dune-land and old clay workings, to see whether infection was less on areas remote from normal nursery conditions and with little plant detritus in the vicinity.

Wound Protectants

Several additions were made to the trial on beech at Westbury Forest. The assessment in 1958 showed that substances varied widely in their ability to protect wounds. Some indeed are deleterious, causing considerable death of cambial tissue and delaying healing. There are wide variations also in the power of protectants to adhere to the surface of the wood. One very promising substance, Arbrex, has been consistent so far in giving protection and also in stimulating cambial growth, but the final assessment must await the felling and dissection of the trees.

Elm Disease—Ceratostomella ulmi

This work is now being broadened to include the testing of selected clones from this country, as well as the routine testing of material from Holland. In addition to grafting, very successful use is being made of a mist propagating frame for rooting softwood cuttings. Plantings of clones in the three trial areas has been completed, and the natural infection in these areas has been increased by inoculation of surrounding natural occurring elms.

Meria laricis

Losses in nursery larch were reported, particularly from North Scotland. European larch was chiefly affected but Japanese and Hybrid larch suffered also. Observation confirmed that one-year European larch seedlings retained their infected needles until after flushing. This may explain early infection and heavy losses in two-year-old seedlings and transplants. A small, preliminary trial of dipping plants in colloidal sulphur before lining-out was made.

A questionnaire designed to give information on such points as the effect on the incidence of the disease of proximity to larch plantations, and the general distribution of the disease in the country, was circulated to all nurseries growing larch. The results await analysis.

Decay and Death due to Fomes annosus

Further survey and experimental work was carried out during 1958, and stump protection was instituted in additional areas.

The survey work helped to confirm the view that infection of new areas was generally on the increase, and with the possible exception of two classes of site, stump protection is likely to be required on all sites. The two types of site on which development of the fungus appears to be restricted, and which require further investigation, are old hardwood sites planted with conifers, and acid peat soils. Development of *Fomes* is exceptionally rapid on old ploughland or ex-arable ground, and early protection has been shown to be particularly required on such sites. In 1958, again, western hemlock was found to be highly susceptible to decay, and restriction of the use of this species in relation to the infection in the site were advised.

In trials of protectants, creosote was still shown to be the most suitable material. Polyborchlorate gave good protection but is not suitable for use in winter, due to poor solubility at low temperatures. Other materials are under trial.

A preliminary investigation into the direct entry of the fungus through extraction wounds indicated that only a small proportion of such wounds become invaded by rot fungi, and that extension of the fungi is usually limited. Infection through wounds in the roots was more serious than through wounds on the stem.

A further experiment on measures designed to eradicate the fungus from infected sites was laid down. This problem has become urgent in view of current efforts to achieve normality in some forests, by felling and replanting immature crops; and it will become increasingly serious in the future. Trials to test the resistance of species, such as the silver firs, *Abies* spp., have also been laid down.

Studies of actual sawmill losses in relation to measurements of decay in the forest, are being made in co-operation with Mr. Dowden of Aberdeen University.

Polyporus schweinitzii

Investigations into the mode of infection of this fungus were made, experiments being laid down to test the ability of the fungus to infect freshly cut stumps, brashing wounds and extraction wounds by means of airborne spores.

FOREST ENTOMOLOGY

By MYLES CROOKE and D. BEVAN

Pine Looper, Bupalus piniarius

Pupal Survey

Slight changes in the areas surveyed were made in 1959. Two forests—Bawtry in Nottinghamshire and the privately-owned Glentanar Forest in Aberdeenshire, which had been surveyed in 1958, were not examined in the current year, and Dunwich Forest was included in the survey for the first time.

The population indices obtained by pupal surveying show in almost every instance an increase over those recorded for the previous year. In only three forests—Cranwich, Swaffham, and Tentsmuir—have the numbers dropped. In the remaining forty areas surveyed in previous years, the looper population was larger in 1959 than it was in 1958. The counts recorded in the 1958 survey were in general very low, and the increase in numbers which has occurred is not in the majority of cases sufficiently great to give rise to any immediate concern. For example, the largest increase amongst the eleven beats of Thetford is Methwold, where the overall average has moved only from 0.16 to 0.6 pupae per square yard, and the highest compartment mean from 1.0 to 3.0 pupae per square yard. In some other areas, however, the increases are much more substantial. The most important of these are:

Cannock Chase, where the forest average has moved from 0.25 to 1.83 pupae per square yard, and the highest compartment mean from 1.4 to 6.8 pupae per square yard.

Tunstall, where the forest average has moved from 0.45 to 3.06 pupae per square yard, and the highest compartment mean from 2.4 to 9.0 pupae per square yard.

The various beats of Sherwood, where the forest averages have moved from between 0.3 and 0.88 to between 2.32 and 6.9 pupae per square yard, and the highest compartment means from between 1.0 and 2.8 to between 6.6 and 20.8 pupae per square yard.

Rendlesham, where the forest average has moved from 2.22 to 11.94 pupae per square yard, and the highest compartment mean from 6.6 to 41.8 pupae per square yard.

The above figures were disturbing, and it appeared probable that artificial control measures would have to be taken at Rendlesham in the 1959 season, whilst a possibility of their being required existed at Sherwood. It is interesting to note that this countrywide upward swing in numbers was in many cases accompanied by an increase also in the weights of individual pupae. This is indicative of increasing potential fecundity.

Study Plot

Populations in the study plot in Thetford Forest remain low, pupal counts carried out during the winter 1958/59 giving between 1 and 2 per sq. yd. A method based on the capture of cast head capsules gives promise in the assessment of all larval stages.

The study of the parasites continues both in connection with the field sample plots, and in the laboratory. It must be recorded that breeding in the laboratory of all three species has been limited by the fact that none of these parasites are numerous in the field collections. *Cratichneumon nigritarius* is inconsistent both in observed copulation and oviposition. The results of successful oviposition suggest a low fecundity. Further there is great variability in the intervals between oviposition, and therefore in the rate at which eggs ripen in the ovary.

It is essential to find some means of breeding laboratory stock in large numbers, in order that detailed work into the effect of nutrition, relative humidity, and temperature, on the fecundity and speed of development, may be carried out.

Studies on Green Spruce Aphis, Neomyzaphis abietina

Infestations of Sitka spruce crops by the green spruce aphis, *Neomyzaphis abietina* Walk., were severe in many parts of the country in 1957. Little is known about the quantitative effect of infestation, and subsequent defoliation by the aphis, on the rate of growth of the trees. It was, therefore, decided to set up a series of plots in various Sitka spruce stands in different parts of the country with the objectives:

(a) of recording the levels of defoliation caused by aphis attack in 1957 and subsequent years for a period, probably of eight or ten years,

(b) of subsequently analysing the increment pattern of the sample trees during the period of observation in an effort to associate the degree of defoliation with a quantitative measure of the of loss increment produced by the attacks.

Thirteen plots, each containing twenty sample trees, have been selected. The plots are situated as follows:

One in a 1927 crop at Alice Holt Forest.

One in a 1931 crop at Bramshill Forest.

Two in the New Forest, one in a 1926 crop in Denny Lodge and one in a 1925 crop at Burley.

One in an approximately 1920 crop on the Lockinge Estate in Berkshire.

One in a 1928 crop at Dovey Forest, Corris Section.

Three in Dovey Forest, Valley Section, in 1927, 1928, and 1929 crops respectively.

Four in Inverliever Forest in 1914, 1925, 1927 and 1938 crops respectively.

As a preliminary, and to gain information on sampling methods, stem analyses have been conducted on twelve trees from a 1926 and 1927 Sitka spruce crop on the Peckforton Castle Estate in Cheshire. This crop was severely defoliated by *Neomyzaphis* in 1952 and also, probably, in 1938. The data have not been fully worked up but preliminary analysis shows that *Neomyzaphis* attack has a detectable effect on the rate of growth of the trees, but it has not yet been possible to find an adequate measure of the extent of this effect. Further analysis of the data will indicate the best sampling methods for assessing the effects of infestation by *Neomyzaphis* in the main series of plots referred to above.

Pinhole Borer, Trypodendron lineatum

The increasing incidence of pinhole borer attack on softwood logs in Argyll has become apparent when the timber in question has arrived at the Cowal-Ari Mill for utilisation. This beetle bores into the logs and its brood develops therein, feeding on a fungus which lines the walls of the tunnels. This fungus causes a dark staining of the gallery walls so that the defects are obvious when the timber is sawn. In addition to attacks by *Trypodendron lineatum*, damage by another timber boring beetle, *Hylecoetus dermestoides*, has also been noticed.

Little is known about the biologies and forest relations of these species in Britain, and investigations into these topics have therefore been commenced. These studies are being carried out in co-operation with entomologists from the Forest Products Research Laboratory at Princes Risborough. During the year a preliminary survey of the situation was carried out, and confirmation obtained that the problem is of some magnitude and practical importance. A series of study plots all in Sitka spruce crops (Glenbranter Forest, Cpt. 141; Glenfinart

Forest, Cpt. 41; and Glenduror Forest, Cpts. 18 and 20) has been set up. In these, sample trees are being felled at monthly intervals, commencing in November 1958, and these logs will be available for inspection and observation during 1959. In that season it is hoped to gather information:

(a) on the biologies of the beetles in question with particular reference to the timing of flight and attack,

(b) on the period elapsing between felling date and susceptibility to attack. In addition, arrangements for experimental studies on the chemical protection of logs from pinhole borer attack have been made.

Equipment for Application of Insecticides

The general policy of testing machinery which appears to be useful for forest insect control operations gave rise during the year to a trial of rotary atomisers fitted to aircraft. These atomisers produce spray droplets by feeding the spray liquid into a rotating cylinder of wire mesh, from the periphery of which the droplets are thrown off by centrifugal force. This device is an alternative to, and is claimed to be an improvement on, the normal boom and jet rig fitted to most spraying aircraft, since the droplet size can be closely regulated to allow of small droplets being obtained and since, further, the variability in size of the droplets is small. These two factors permit good coverage to be obtained with low rates of application, and this, of course, has considerable economic advantage.

The trial was sited at Tentsmuir Forest in two compartments of P.24 and P.25 Scots pine and Corsican pine, which harboured countable but not very high numbers of pine looper larvae and of larvae of the sawfly *Acantholyda posticalis* Mats. These compartments were sprayed with a 10% DDT preparation, one compartment receiving one gallon of spray per acre and the other one half-gallon of spray per acre. Trays had been set out on the forest floor and the dead and moribund larvae falling on to them after spraying were counted. These assessments were continued until no more larvae were found on the trays, after which the sections of canopy immediately above the trays were heavily over-dosed with a DDT fog emitted from a Swingfog machine. Then further counts of larvae falling to the trays were made. In this way it was possible to compare the numbers of larvae killed by aerial spraying with the presumed total number of larvae present i.e. those killed by spraying *plus* those killed by the heavy fog application. The results indicated that approximately 80% of the population was killed by spraying at the rate of one half-gallon per acre, and that the mortality in the compartment sprayed at the rate of one gallon per acre was approximately 99%. As a first trial these results are promising, and further tests with rotary atomisers are being planned.

Larch Bark Beetle, Ips cembrae

The distribution of this bark beetle was resurveyed during the year and Part III of this Report contains a brief article dealing with this topic (p. 167).

Larch Sawfly, Anoplonyx destructor

It is planned to undertake an intensive investigation of this larch feeding sawfly and preliminary work has been carried out in the year under review with the object of setting up a permanent study plot. There are as yet, however, no results to record.

Semasia diniana

It was suggested in last year's Report that the epidemic of this insect at Hope Forest, Derbyshire, would have collapsed naturally by 1958. This, in fact, did occur and because of the consequent shortage of material the studies on this insect have been discontinued.

Advisory Work

One hundred and twenty-three enquiries were dealt with during the year, eighty-two originating from Forestry Commission and forty-one from private sources.

GREY SQUIRREL CONTROL

By K. D. TAYLOR

The large-scale programme of population study by live-trapping, which has been in progress since 1956 in Alice Holt Forest, is now virtually at an end. The next stage is an all-out effort to recover as many of the marked animals as possible. Already valuable information on cage trapping methods has been obtained, and additional information on shooting and tunnel trapping techniques will be available when the field work is complete. During routine trapping at Westonbirt Arboretum, the efficiency of various approved and experimental humane traps was compared.

A preliminary survey of squirrel populations in the Central Lowlands of Scotland has been made in preparation for field trials of various poisons. It seems clear that sufficient squirrels are to be found in the area to enable such trials to be conducted.

A distribution survey of red and grey squirrels is being carried out on a parish basis in England and Wales, and should be ready for publication in about a year's time.

Demonstrations of trapping methods and exhibits at shows have occupied a good deal of time. It is hoped that the release of the recently completed film on Grey Squirrels, which lays particular emphasis on control, will often serve as an acceptable substitute for personal demonstrations.

FOREST MANAGEMENT: INTRODUCTION

By F. C. HUMMEL

The work under the heading Forest Management is carried out by four sections —Mensuration, Census of Woodlands, Working Plans and Economics. The first two of these sections were formed in 1946 and 1947, the other two in 1956. The reports which follow give an account of the year's work of each section, and indicate the change of emphasis that has taken place within the last few years.

The Working Plan section has developed very rapidly and has already been fulfilling for some time the very considerable responsibilities which are referred to in the sectional report. Less spectacular but substantial progress has been made in developing the wider and more complicated field of work in the economics of forestry. Mensurational activities have continued at approximately the same level as during the past few years, but the work of the Census of Woodlands section, which is responsible for maintaining up-to-date national statistics of forest areas, growing stock, increment and fellings, has been reduced considerably for two main reasons; in the State forests the more detailed working plan surveys now provide the necessary information, and in the private woodlands less detail is now required than formerly.

In several projects the sections have acted jointly. Thus the Census, Mensuration and Economic sections were all concerned with the collection and presentation of statistics and forecasts required by the Cabinet Committee which reviewed National Forest Policy in 1958: and the Census and Mensuration sections shared the responsibility with the Working Plan Section for producing some of the technical instructions in the Working Plans code.

In addition to the work within the sections, there have been some general activities mainly in connection with international organizations. The writer as Deputy Leader of Section 25 of the International Union of Forest Research Organizations co-operated closely with the Leader of the section, Professor Firat, who spent several months in England during the year.

Four working parties were established dealing respectively with: the use of aerial photographs in forest inventories, the use of statistical methods in forest research, methods of determining increment in tropical forests, and the development of indices for determining the growth potential in forest areas. The writer deputized for the leader of Section 25 at the meeting of the Permanent I.U.F.R.O. Committee at Brussels in September, 1958, and also attended the meeting of the Arbeitsgemeinschaft für Forsteinrichtung, at Koblenz, to which he had been kindly invited. He also was a member of a sub-committee of the British Commonwealth Forestry Conference, which was appointed to examine the forest inventory questionnaires in the "country" statements for Commonwealth Forestry Conferences.

Early in 1959 the writer was released from his normal duties for six months in order to undertake an assignment in Rome for the Food and Agriculture Organization of the United Nations. The assignment was to act as co-ordinator and editor of the Far Eastern Timber Trends Study, which is a joint project of that Organization and the Economic Commission for Asia and the Far East.

WORKING PLANS

By D. R. JOHNSTON

Introduction

The responsibilities of the Working Plans Section have now been defined in the Working Plans Code as follows:

(a) To conduct research into management problems and methods with a bearing on working plans.

(b) To make available within the Commission the results of investigations on working plans in other countries, and to provide information about the activities and proposed activities of bodies such as the Ordnance

Survey, Soil Survey, Geological Survey etc. which may be of value for working plan purposes.

(c) To comment, as required, on matters arising out of the working of the Code, including questions of interpretation.

(d) To advise local staffs on the preparation and maintenance of working plans, including the collection and presentation of data so that a reasonable degree of consistency may be maintained throughout the Forestry Commission.

(e) To maintain a nucleus of specialist foresters trained in working plan survey methods, who will be used to develop new techniques, to train local staff and to assist them where necessary in carrying out working plan surveys.

(f) To give expert opinion on working plans submitted for approval.

The second year's work of the Section has been concerned principally with the completion of the Working Plans Code, and with the further development of methods and procedures for carrying out working plan surveys. Little time has been available for investigations into fundamental problems of management.

Liaison with Other Departments

A close liaison has been maintained with such organisations as the Ordnance Survey, Soil Survey, Directorate of Overseas Survey, the Geological Survey, the Ministry of Housing and Local Government and the Department of Health for Scotland. As a result of the report submitted by an officer of the Ordnance Survey in collaboration with the Working Plans Section, an instructor was assigned by the Ordnance Survey to conduct two four-week survey courses which were attended by foresters from the Management Section, the Education Branch and several Conservancies. In addition, six Management Section foresters attended a three weeks' course in air survey at the Directorate of Overseas Survey.

The Working Plans Code

The Working Plans Code was completed in draft by the middle of the year. Four courses were then held at Northerwood House for divisional officers and district officers, and subsequently two-day courses were held in Conservancy offices. By the end of the year eight such courses had been completed. As a result of these discussions with the technical and executive staff, over one hundred and twenty amendments were made to the draft Code and the final version is now (May 1959) being prepared for Departmental circulation.

Working Plan Techniques and Procedures

More than 100,000 acres have now been surveyed for working plan purposes by Management Section field staff. As a result of the experience gained in the course of this work, routine procedures for crop assessment and forest inventory are now in operation. Detailed instructions on these procedures are issued to specialist field staff in the form of Provisional Working Plan Technical Instructions, and when they have been well tested in the field they will be issued from time to time as part of the Working Plans Code.

Working Plan Field Work

Working plan surveys were completed at Cairn Edward, Ae, Dalbeattie, Inverinate, Eileanreach and Glenurquhart Forests during the year, and are in progress at the Forest of Dean, Thetford Chase, Craig Phadrig, and Assich Forests.

FOREST ECONOMICS

By A. J. GRAYSON

The year saw the completion of the academic year spent by the Economist at Oxford University. In the latter part of the course, particular attention was devoted to statistics and its application to economics, with special reference to forest production and the timber-using industries.

Economics of Hardwoods

An investigation is being undertaken on the economics of hardwood growing and on the consumption of hardwood timbers in this country. Most of the data have now been assembled. The statistical gaps have been found to limit severely the possibilities of economic analysis, but in spite of this, some interesting and potentially valuable results have been produced. For instance the demand for imported hardwoods appears to be markedly price-elastic, that is, for a 1% reduction in the price of hardwoods relative to other basic materials, an increase of more than 1%—probably 2% in fact—may be expected in the volume demanded.

One aspect has proved difficult to study. This concerns the supply side of roundwood and manufactured timber production, in which field the derivation of supply schedules (showing the rates of production called forth at different prices) is an essential part of the study. The necessary statistics (such as costs of factors of production, prices paid for products, and volume of production) are for the most part unavailable or, as with the Board of Trade statistics, insufficiently identified to allow a separation of the hardwood from the conifer element.

Enquiries have been extended to the plywood made from hardwoods, the total of home production and imports amounting to a volume (of roundwood equivalent) equal to about one third of that absorbed in hardwood sawnwood.

Where volume yields are fairly steady, variations in price per Hoppus foot are obviously of great importance in determining income and overall profit; and accordingly the collection of price data has been given special attention. Some annual price series have been compiled, covering periods up to 75 years in length, for hardwood species sold standing from individual estates. A review of the literature has brought to light occasional references to past standing prices, which however suffer from a disadvantage still apparent today, namely that too often prices are inadequately related to technical characteristics of the tree, the site from which it came, and the method of sale.

Some detailed costs have also been compiled: these have come from internal Forestry Commission records and emphasise the heavy burdens involved in hardwood establishment on old woodland sites. It is hoped to publish the material gathered on this subject of hardwood economics as a whole, in the course of the ensuing year.

Assessment of Profitability

The question of profitability, its assessment and the achievement of the highest profits within the limits of other objectives, remain at the heart of forest economics, just as these questions lie basically at the heart of all economic theory. A variety of criteria of profitability were adopted in calculations made in the course of the forest policy review of 1958. In accordance with the desired object of making the management of Commission forests more economic, a form for the calculation of various measures of profitability has been devised which is intended for use by field officers. Some work has been done on the elucidation of the appropriate measures of profit for application to state forestry. Maximum discounted revenue (present worth) per £ of capital invested appears to have strong claims as one of the most appropriate measures of profitability in state forestry. Work on profitability has extended to the closely related field of plantation valuation.

While the methods of appraising profitability, and the means of calculating which course of action is likely to provide the greatest profit, are fairly clear, the costs and prices to be entered in the formulae are very uncertain, and much of the work in this Section will in future be devoted to evaluation of the possible developments in costs, and prices, of the final product in the form of round timber.

Costs of Individual Operations

On the side of operational costs, two new projects have been started. One concerns the cost of production of seedlings in nurseries. In this enquiry an attempt is being made to relate numbers produced to a range of monetary and physical inputs devoted to the growing of seedlings in a number of nurseries. The other project relates to a sawmill costing (completed in April, 1959) which is designed to express sawing cost per unit of sawn outturn, in terms of measurable characteristics of logs. The aim in this field of research is to investigate the costs of processing roundwood logs of different sizes in various plants, and to relate these costs to the value of manufactured wood.

In addition to these two projects, further observations have been made on the desirable intensity of road-making, bearing in mind not only present costs but also the dynamic effects introduced by changing ratios of the costs involved (primarily road charges relative to costs of haulage to roadside) and money depreciation, this latter affecting the real burden of interest.

Timber Prices

On the subject of prices of standing timber, a preliminary enquiry has been undertaken of prices received in sales of conifer thinnings in East (Scotland) Conservancy. This has provided a useful illustration of the fact that variation in price cannot readily be related to certain measurable characteristics of the crop and site. This result, it is believed, is not at all typical, and further work is necessary in this field if benefits are to be obtained. (The major exception was the positive relation found between price and average volume of tree). Insofar as physical characteristics do affect market price, it is clearly of great importance that foresters should know which attributes generally have an effect on prices received.

Preparatory work has begun on bringing together certain statistics covering private forestry, for use in any reviews of the economic situation which may be undertaken. Particular attention is here again called for in evaluating the relation of costs to prices.

STUDIES OF GROWTH AND YIELD

By A. M. MACKENZIE and J. M. CHRISTIE

During the early part of the year a considerable amount of time was devoted to work connected with the Cabinet Working Party on Forest Policy, with the preparation of forecasts of production, and testing new techniques for Working Plan Surveys. In consequence, the progress on a number of projects started last year was much less than had been hoped for. Thus the preparation of the conifer stand tables, and the extension of the conifer yield tables, have continued but slowly, although several basic formulae for use in the extension of the conifer yield tables have been tested. A preliminary yield table for poplar has been produced, and the yield tables for the silver firs, *Abies grandis* and *Abies nobilis*, have been prepared for publication. Very few new sample plots were established during the year, and the programme of plot measurements had to be curtailed because of the large increase of working plan survey work.

Yield Tables and Other Tabular Aids

The yield table for *Abies nobilis* mentioned in the 1958 *Report* was completed. This species has a rate of growth comparable to Norway spruce, but at 50 years shows a slightly higher total volume production per acre. It has the highest crop form factor of any conifer for which yield tables have been prepared. In constructing the yield table, a crown thinning treatment was assumed, in contrast to low thinning which has been used in the preparation of all the other conifer yield tables. This was found necessary owing to the rather irregular canopy structure of *Abies nobilis* stands, especially in the early years.

The yield table for *Abies grandis*, which was completed in 1957, will be published with the *Abies nobilis* yield table. Neither of these species has obtained its maximum mean annual volume increment at 50 years. Height growth for both species in this country is similar to that on the Continent, but their total volume production appears to be somewhat higher.

Tables giving the growth of poplar under various assumed treatments were prepared for the Hardwood Pulpwood Planting Committee. From this study of poplar, it was found that a relationship of the various crop characters with height existed, in the same way as for conifers. Although only a very limited amount of data were available, it was therefore possible to prepare a *Preliminary Yield Table for Poplar*, by employing the same techniques as had been previously used for conifers. This yield table has now been published, as Forest Record No. 40. (H.M.S.O., 1s. 6d.). It was found that total volume production at a given height is dependent upon the initial planting distance. Although close spacing will give a higher initial yield, the data suggest that there will be little difference in the final total volume production per acre, irrespective of spacing. This observation is confirmed by data from the Continent. Although this yield table is based mainly upon data for Hybrid Black poplars, the data from the few plots of Balsam poplar suggest that it will also be applicable to these, at least in the younger age classes. It is thought that the Balsam poplars may eventually show greater girths and volumes at given heights than do the Hybrid Black Poplars, particularly in the cooler, wetter parts of the country for which they appear to be better suited. The data did not readily lend themselves to the more usual definition of quality class by ten feet "top height" intervals at 50 years of age, and as the amount of data for crops older than 30 years was very limited, quality classes were based on the expected height at 40 years, giving three quality classes, with heights of 110 feet, 95 feet and 80 feet at this age. The exceedingly fast growth of individual trees is not, however, equalled by the total volume production per acre because of the extreme space and light requirements of poplar. At 40 years of age, total volume production is 5,000 hoppus feet per acre in Quality Class I, but only 2,450 hoppus feet per acre in Quality Class III. These yields, although greater than those of other broadleaved species in this country, are considerably lower than those of such conifers as Douglas fir or Sitka spruce.

Because of the volume of other work, progress has not been maintained on the extension of the conifer yield tables, and it has only been possible to explore the use of several basic formulae. The preparation of the conifer stand tables is proceeding slowly but steadily.

A satisfactory, simple sampling scheme has now been evolved for the prediction of basal area increment from increment cores, and work is continuing to test if this sampling scheme is applicable for the estimation of volume increment in young fast-growing coniferous crops.

Permanent Sample Plots

786 permanent sample plots are now managed by the section, 405 in England, 239 in Scotland and 142 in Wales. 121 of these plots were remeasured during the year, 64 in England, 30 in Wales and 27 in Scotland. Only 14 new plots were established. One Sitka spruce plot in Wales was abandoned because of windblow.

Wind damage has caused a number of plots to be abandoned in recent years because the stocking in them was so reduced that they were considered to be of no further use for yield table purposes. A few have since been reclaimed so that subsequent increment and recovery from wind-blow may be studied. Of these, the most interesting is a plot of Japanese larch at Benmore, Argyll. This was severely devastated in the winter of 1935/36 when 190 trees per acre were blown, reducing the basal area to 33.4 square feet, quarter girth measure, per acre and the volume to 720 hoppus feet. No further wind damage has occurred, and the stocking at 50 years of age, 22 years after the wind-blow, is now equivalent to that given in the Japanese larch yield table at 50 years; the basal area is 82.2 square feet, quarter girth, per acre and the standing volume 2,936 hoppus feet. Total volume production to date is 4,766 hoppus feet per acre, which is just over 1,400 hoppus feet less than that given in the yield table.

Up to the present, the only adequately replicated thinning experiment has been the one in Norway spruce on the Bowmont Forest Estate, near Kelso, Roxburgh. Two further replicated thinning experiments are planned, one in Sitka spruce in Scotland and one in Scots pine in England. Some preparatory work was necessary before starting such a large-scale experiment, and seven temporary plots were established in Brecon Forest, South Wales, to test various crown thinning prescriptions, ranging from the normal light crown thinning to an exceptionally heavy crown thinning. These plots will be retained for about ten years to study the response to these treatments.

In the past we have primarily studied the thinning treatment and yield in even-aged stands of a single species. Because of the interest now being shown in conifer/hardwood mixtures, largely as a result of the increased area of such crops now being planted, a preliminary study was made in a 54-year-old, even-aged mixed conifer/hardwood plantation at Hursley Forest, Hampshire, in order to obtain data that will give some guidance to the possible future treatment of even-aged, mixed stands.

Management Indicator Sub-Compartments

In November 1957, a departmental memorandum was issued extending the use of the general tariff tables for conifers, previously confined to thinnings, to the volume assessment of the standing crop. The location of these indicator sub-compartments will, in future, normally be determined as part of the forest working plan. These areas are usually of up to 10 acres in extent, and they are measured by the local staff. The first measurements are being sent to the management section, and data from 135 indicator sub-compartments, 53 in England, 35 in Wales and 47 in Scotland have been received.

These Indicator Sub-Compartments are primarily intended to serve local staff as a silvicultural control, to provide information on the development of a species or mixture growing on a particular site and receiving a prescribed treatment. The data thus obtained may, with experience and care, be applied to similar crops growing under similar conditions elsewhere in the region, and they may, therefore, in time serve as a guide to choice of species, length of rotation, likely response to thinning treatment, underplanting etc. Individually, they will provide information on the volume increment of the particular stand, and on local deviations of growth from those given in the yield tables. Collectively, the data provided from these areas all over the country will enable deviations of growth from the yield tables to be studied, and will in time permit calculations to be made of the differences in increment between the yield table values which relate to one acre of fully stocked woodland, and the data from the Indicator Sub-Compartments, which normally relate to more than one acre of woodland and often include pockets of inferior growth as well as parts of rides and rackways. They will, in addition, serve to supplement the data provided by our permanent sample plots.

Other Work

A considerable amount of time has again been devoted to various miscellaneous activities. Co-operation with the Utilisation Development Section and with the Forest Products Research Laboratory at Princes Risborough has continued. During the year a further 1,000 pit props of Scots pine, Sitka spruce and Norway spruce have been tested from Scotland and the Border Forests.

A consignment of 120—130-year-old Turkey oak was sent for timber testing from Pusey Estate, Berkshire. This stand, which was marked for thinning, had a top height of 113½ feet, a standing basal area per acre of 226.4 square feet quarter girth, and a standing volume of 8,790 hoppus feet per acre. The height is considerably more than that for Quality Class I pedunculate oak and the basal area and volume are almost three times as much, so it does emphasise the superior rate of growth of Turkey oak. Even after thinning the stocking in this stand will be double that given in the oak yield table for Quality Class I pedunculate oak of this age.

In addition to this work, measurements were taken of coppice crops of sycamore, ash, lime, birch, oak, alder, poplar and willow, to provide information on the likely dry weight yield per acre of these species for the Hardwood Pulpwood Planting Committee. Estimates of the yield of selected species of hardwood, under both forest conditions and conditions of "free growth", were also made.

CENSUS OF WOODLANDS

By G. M. L. LOCKE

During the past year only a very small amount of survey work has been completed on the Census Revision, this being due to the decision made last year to discontinue field work. The resurvey of the County of Northampton commenced in January 1959 and by the end of March about 14,000 acres out of the total of 30,000 acres had been completed. This county will probably be the last to be resurveyed under this revision system.

Future census work will be based on sample surveys which will give sufficient information for an assessment of the woodland area by forest type, age and species, for groups of counties. These surveys will be mainly confined to privately-owned woodlands, since figures of area, volume and increment for Forestry Commission forests should largely be available from Working Plan surveys which are already taking place in certain forests. Although a sample survey of private woodlands is unlikely to be undertaken for some years, an assessment of the national position will continue to be made annually from felling, planting and other returns.

The staff who would normally have been engaged on Census Revision work have been used mainly on working plan surveys in Forestry Commission areas. The survey methods employed in the two operations have been kept as similar as possible, so as to ensure that data collected as a result of survey work in privately-owned and Forestry Commission woodlands will be comparable. This naturally has resulted in a close liaison with the Working Plans Section, and the new Working Plans Code embodies many definitions and procedures which have been tested and found satisfactory on the Census Revision.

Other large projects on which the Census section has been involved have been the preparation of the 1958 Forest Inventory for the Food and Agricultural Organisation and the compilation of long-term forecasts of yield, within specific areas, for pulpmill and other projects.

DESIGN AND ANALYSIS OF EXPERIMENTS

By J. N. R. JEFFERS

As in previous years, the most important aspect of the work of the Statistics Section has been that of advising all other sections of the Research Branch on the design and analysis of their experiments and surveys. The Section was strengthened by the appointment of Mr. R. S. Howell as Assistant Statistician, and by his posting to Edinburgh to enable the Section to keep in closer contact with the silvicultural work in the north, and with the Work Study Section. Advisory work on the design and analysis of forest experiments has also been undertaken for certain Colonial Forest Departments, and for other organisations and research stations interested in forest problems e.g. the Forest Products Research Laboratory and the Tropical Products Laboratory. Several officers from such departments have also spent periods of from one to six weeks working with the Section, learning general statistical theory and the special applications of that theory to forest problems.

The main development in the analysis of data arising from forest research and management has, however, been the transfer of virtually all computing undertaken by the Section from desk calculating machines to a Ferranti "Pegasus" computer. This transfer has affected profoundly the organisation of the Section, and a large proportion of the work of the past year has been directed towards the necessary reorganisation of the Section and the programming of the computer to handle the wide variety of analyses regularly encountered.

The Statistician was invited to act as consultant to the Food and Agriculture Organisation at Geneva between the 26th and 30th of May for an international meeting on the collection and analysis of forest accident statistics, and subsequently prepared a report on the methods recommended.

Work on new applications of statistical methods of design and analysis has necessarily been curtailed owing to reorganisation. A number of projects have, however, been continued, though none completed. The most important of these are the applications of multivariate analysis, new methods of analysing perennial crop data, and the investigation of growth curves basic to forest mensuration.

Experimental Design

Designs have been provided for more than 80 experiments during the year. It has been noticeable that the experiments for which these designs were required have been changing from direct tests of relatively simple hypotheses to tests of more complex hypotheses involving the interaction of many factors. Experiments on the manuring of pole-stage conifers, for example, have been required to assess the changes in nutrients in the soil, in the foliage, and in the timber; the changes in growth of the trees; and the changes in the properties of the timber produced. Experiments on thinning of plantations have been required to assess not only the changes in volume production of the crop, but also the effects of the several treatments on timber properties and site factors. There has, therefore, been a distinct trend towards the establishment of smaller numbers of experiments, but each experiment of greater complexity and requiring the measurement of larger numbers of factors.

Greater attention has also been paid to the possibility of using old experimental material for new experiments, when the objects of the first experiment have been fulfilled. This is of particular value in making the most economic use of old establishment experiments for further work on methods of thinning, etc. Provision has also been made in the initial design of short-term experiments for the subsequent use of the material in later experiments.

The design of thinning experiments has received particular emphasis from the impending establishment of a new series of investigations into this important subject. The need for confining the experimental treatments to only some of the combinations of the factors to be studied, the need for large experimental units, because of possible 'edge effects' and the difficulty of providing adequate replication, all render the more usual experimental designs somewhat unsatisfactory. A number of alternative designs have been considered, and it is hoped that more efficient designs for such experiments will be found.

Survey Design

There has been the usual variety of survey problems, including surveys of insect populations, forest accidents, moisture content of fresh-felled timber, costs of establishment of plantations, and quantities of woodwaste. The main work in this field has, however, been the design of a comprehensive survey of the growth, nutrition, and timber properties of Sitka spruce. This survey seeks to establish the effects of site on the three most important aspects of the growing of Sitka spruce, and is being carried out in co-operation with the Forest Products Research Laboratory.

Analysis of Experiments and Surveys

Analysis of 426 experiments, representing 2,730 individual analyses, has been undertaken. Of these, 82 experiments, or 960 individual analyses, were done on a Ferranti Pegasus Computer. This represents a marked increase in the number of experiments analysed, and in average number of individual analyses per experiment.

The Pegasus Computer was chosen as the most suitable for the work of the Forestry Commission Research Branch, after careful consideration of the many digital computers now available. It is a medium-sized, multi-purpose machine of great versatility and high computing speed. It is relatively easy to "programme", and contains a large number of built-in checks, thus ensuring great reliability without serious loss of speed. A good library of standard sub-routines is already available, and new programmes are being written at a rate of about 400 per year. For scientific purposes, the main input and output mechanism uses punched paper tape, which is easier to prepare and more convenient for carrying about than punched cards. A number of Pegasus computers are situated within reasonable distance of the research station, but use has primarily been made of the closest, only ten miles away, and working time has been made available to the Forestry Commission on this machine.

To enable programme and data tapes to be prepared, equipment for the punching, editing and printing of paper tape has been purchased and installed at Alice Holt. The staff who were previously engaged in computing on desk calculating machines have been trained to operate this tape-punching equipment, and are now fully employed in the preparation of data for the computer and the despatch of completed computations.

Programmes are available, or have been written, to deal with more than eighty per cent of the normal work of the Section, including analysis of variance, regression and multiple regression, multivariate analysis, and curve fitting. Programmes for other types of calculations can be provided fairly quickly by the use of one of the two simple coding systems available on Pegasus, i.e. the matrix interpretive scheme, and the Pegasus Autocode, and, in general, no difficulty has been experienced in providing a suitable programme within a reasonable time for any problem that arises. Most of the programming effort of the Section is therefore directed towards further generalisation of programmes, thus enabling a single programme to undertake a wider variety of problems.

As a result of this reorganisation, the amount of computation that can be undertaken by the Statistics Section has been very greatly increased. Previously, the amount of computation had been severely limited by the staff available, with the result that only a small part of the work needing analysis could be undertaken, and the more ambitious analyses, e.g. for multivariate analysis, could not be considered. Now that the reorganisation has been completed, as much or as little computation as is required can be undertaken both speedily and economically, and it is expected that this facility will greatly increase the scope and the progress of the research programme.

Standardisation of Measurements and Tests of Instruments

Work has continued on these subjects in collaboration with the Working Party of Section 25, International Union of Forest Research Organisations.

UTILISATION DEVELOPMENT

By E. G. RICHARDS

Home-grown Pitprops

The destructive testing of home-grown pitprops at the Forest Products Research Laboratory was continued.

The Use of Timber in Building

The survey as to the types, dimensions and qualities of imported softwood used in the building of traditional houses was continued. In England and Wales 50 local authorities, selected by random sampling, were approached and visits were made to 46 of them. They included 6 County Boroughs, 15 Boroughs, 15 Urban Districts and 10 Rural Districts. Where possible the architect, surveyor or other local authority official was interviewed, and in some districts, the timber used on the municipal building sites was examined in order to make notes on the sizes of timber delivered, and on the incidence of defects in both carpentry and joinery timbers.

At each interview the local authority officials were asked whether they had any experience of home-grown softwood in house construction, and if so what, if any, disadvantages had been encountered. They were also asked which defects in imported timber used at the present time caused most concern, whether they had a preference for any particular species of softwood, and the reasons for that preference, and finally which were the longest lengths and greatest widths normally required for their housing schemes. Notes were also made on the "Carpenter & Joiner" clauses of the local authority specifications.

A start was made on a similar survey for Scotland where it is intended to approach all local authorities who are constructing more than 100 houses per annum; by the end of the year under review 12 had been visited. The results have since been published as Forest Record No. 42, *Use of Home-Grown Softwood in House Construction.* (H.M.S.O., 1s. 3d.).

Yields of Hardwood Coppice

The survey commenced during the year ending March, 1958 was completed. The results are given in Tables 26 and 27 following.

Table 26

Yields of Green Wood (including Bark) Measured to 2 inches and 3½ inches Top Diameter, per Acre

Species	Age	To 3½ inches Top Diameter		To 2 inches Top Diameter	
		Gross Yield Tons	M.A.I.* Tons	Gross Yield Tons	M.A.I.* Tons
Alder	20	38.57	1.93	55.04	2.75
Ash	32	40.78	1.30	50.33	1.57
Birch	31	61.74	1.99	69.64	2.24
Lime	12	16.87	1.40	25.56	2.13
Lime	32	39.04	1.22	—	—
Oak	37	75.80	2.05	86.55	2.34
Poplar	25	154.53	6.18	161.0	6.44
Sweet chestnut	16	—	—	32.16	2.01
	26	92.04	3.54	—	—
Sycamore	16	18.76	1.67	26.68	1.67
	30	56.4	1.88	—	—
Willow	25	112.72	4.51	118.18	4.75

Notes: (a) The figures for Sweet chestnut at 16 years are taken from previous work (Forest Record No. 30) and relate to material measured to 2½ inch top diameter overbark.

(b) The figures for lime, Sweet chestnut and sycamore at ages of 32, 26 and 30 years respectively are available only in terms of material of 3½ inch top diameter. The yields for material measured to 2 inches top diameter would be somewhat higher (see other species of comparable age).

(c) *M.A.I. = Mean Annual Increment $= \frac{\text{Gross Yield}}{\text{Age}}$

Table 27

Yields of Dry Wood (including Bark) Measured to 2 inches and 3½ inches (top diameter) per Acre

Species	Age	To 3½ inches Top Diameter		To 2 inches Top Diameter	
		Gross Yield Tons	M.A.I.* Tons	Gross Yield Tons	M.A.I.* Tons
Alder	20	18.71	0.94	26.73	1.36
Ash	32	23.00	0.73	34.24	1.07
Birch	31	34.82	1.12	39.26	1.27
Lime	12	7.72	0.64	11.69	0.97
Lime	32	17.86	0.79	—	—
Oak	37	42.80	1.16	48.87	1.29
Poplar	25	65.37	2.61	68.13	2.71
Sweet chestnut	16	—	—	16.08	1.0
	26	45.9	1.77	—	—
Sycamore	16	10.25	0.64	14.57	0.91
	30	30.84	1.03	—	—
Willow	25	61.58	2.46	64.59	2.58

Notes: (a) Dry weight yields have been calculated from the green weight yield by using moisture content figures (see Forestry Commission Research Report 1955, pp. 112-118).

(b) *M.A.I. = Mean Annual Increment $= \frac{\text{Gross Yield}}{\text{Age}}$

The sample plots were chosen from coppice woodlands which had the following features: (i) Good stocking (ii) Satisfactory form (iii) Satisfactory height development. They did not represent *average* growth, but were regarded as examples of the particular species growing on sites suitable for them. Some species were, of course, more appropriate to their particular site than others were to theirs. Oak, ash, sycamore and lime were on sites which could carry any of these species with moderate success. Birch, on the other hand, was on a site which would be described as a good site for hardwoods, whilst alder, willow and poplar were on sites which were ideally suited to these three species.

Elm

In collaboration with the silviculture section, visits were made to certain sawmills to attempt to identify botanically the various types of elm timber recognised by the home-grown timber trade, with a view to obtaining breeding material from trees producing timber with desirable properties. The work is continuing.

Preliminary Survey of Specific Gravity and Moisture Content of Sitka Spruce

Samples were collected in order to obtain some indication of the order of differences found in the moisture content and specific gravity of Sitka spruce within the tree, between trees on the same site, and between trees from different sites. This information was used to design a full-scale investigation into these characteristics for all the major coniferous trees grown commercially in this country; this investigation is now under way.

Intensive Investigation at F.P.R.L. into the Properties of Home-Grown Timber

A comprehensive enquiry into the properties of home-grown timber with reference to their silvicultural treatment (including the relationship between site factors and timber properties) was designed jointly by the Forestry Commission and the Forest Products Research Laboratory (Department of Scientific and Industrial Research). The first species to be examined is Sitka spruce, and work on this began in December, 1958.

Fence Post Trials

The first assessments in the fence post trials laid down in the previous year were made by applying a steady 50 lb. horizontal pull at the top of the post.

As might be expected during the early stages of the experiment, no failures were recorded.

Thinnings House

The three-bedroomed house referred to in the 1958 *Report* was completed and occupied during the year. Plans have been prepared for the erection of a similar building in mid-Wales in order to see how the timber will behave in a region with a much heavier rainfall.

Extractives from Wood and Bark

Work carried out by the British Leather Manufacturers' Research Association is reported by Dr. D. E. Hathway on p. 115. The work mainly involved tannin determinations to study the rate at which Sitka spruce tan bark deteriorates when left on a felled log, and also tannin wax and dihydroquercetin determinations in Douglas fir bark.

A sample of leather tanned with Japanese larch bark was made up into slipper soles and knife sheaths and displayed at the meeting of the British Association in Glasgow.

A start was made on a survey of the literature on extractives from bark. The work is being undertaken for the Commission by the Tropical Products Institute.

MACHINERY RESEARCH

By R. G. SHAW

The main event of the year was the organisation of the first large-scale exhibition in this country, devoted entirely to machinery suitable for forest operations. This event was held at Blackbushe near Camberley on the 28th and 29th of May, 1958. Over 70 individual exhibitors took stands and it is estimated that over 3,000 visitors attended. It is intended to organise similar exhibitions at intervals of 2-3 years.

Progress made on individual forest operations is as follows:

Extraction and Conversion of Forest Produce

The self-propelled sulky mentioned in the last report was entered in the Royal Agricultural Society's competition held in 1958, where it was awarded a bronze medal. This machine has been much improved, but the maximum load that can be carried using the principle employed is limited to 1,200 lb.

A powered conveyor has been developed which is capable of feeding a pendulum cross-cut saw giving a joint output of over 2,000 linear feet per hour. A complete conversion plant on the line system is being investigated.

Power Saws

A steady flow of new light one-man power saws of both British and foreign manufacture is coming onto the British market. New schedules for testing these saws on an international basis are being drawn up by the Food and Agriculture Organisation, and the necessary equipment to carry out these trials in this country is being prepared.

Drain Cleaning

This remains a problem to which a real solution has not yet been found for forest drains. Several large machines exist which can cut new drains very well, but none of them can deal with the old drains in a plantation. The new light machine mentioned in the last report is still under development. A new tractor-mounted machine, intended expressly for cleaning forest drains, is in the design stage.

Winches

The lightweight portable powered winch mentioned in the last report has been improved and is now on the market.

Tractors

No large-scale tractor trials have been carried out during the year. Four-wheel drive continues to be a great asset in improving the performance of wheeled tractors.

Load-Carrying Vehicles

The value of wheeled vehicles used in the forest is often limited by their inability to travel over rough and unroaded country. This particularly applies to fire fighting and the carriage of men and equipment to remote areas. Recent experiments have shown how a simple conversion to very large wheels can improve the cross-country performance out of all recognition. A test vehicle has been built, and the lessons learned will shortly be applied to a four-wheel drive vehicle with a payload capacity of 1 ton.

THE LIBRARY AND PHOTOGRAPHIC COLLECTION

By G. D. KITCHINGMAN and I. A. ANDERSON

Library 945.14

The number of books in the library on the 31st March, 1959 was 3,265, an increase during the year of 233, of which 119 were bought and the remainder received by gift or exchange. 717 books are now on permanent loan to Sectional libraries. Other loans of books increased from 821 to 926. 229 publications were borrowed from outside libraries. Another 49 volumes of periodicals were bound, bringing the total to 1,355.

Archive Section

The files in this section form a valuable collection of typescript reports, translations etc., which has been carefully indexed and cross-referenced in the library card catalogue. Much material was added to it during the year.

Documentation

Progress is steady but slow. The number of cards in the indices (card catalogues) is now about 87,500, equivalent to about 30,000 references.

Bibliographies

The number of references in the Subject card-catalogue is now well over 40,000, and in the Geographical catalogue about 8,000. With indices of this size, and containing as they do only references considered relevant to forestry in the British Isles, our bibliographies, especially those which have been annotated, are now reasonably good. Requests for them are on the increase, especially from officers detailed to give lectures or attend study courses.

The bibliography of British forest literature is also making headway, but rather slowly.

Translation Section

The more important translations completed were noted in the Library Quarterly. These now total 99.

A.S.L.I.B.

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

Photographic Collection

The official collection of colour slides to illustrate lectures has once more been in great use. 10,368 issues of slides were made during the year. Figures for the past 7 years show:

For	1952/3	652	slides issued on loan
„	1953/4	1,216	„ „ „ „
„	1954/5	5,081	„ „ „ „
„	1955/6	5,458	„ „ „ „
„	1956/7	7,740	„ „ „ „
„	1957/8	8,640	„ „ „ „
„	1958/9	10,368	„ „ „ „

The number of colour slides in the collection increased from 4,575 to 5,700. 600 photographs were loaned to Exhibitions, Agricultural Shows etc.

Film distribution amounted to 180 films loaned during the year, compared with 166 last year and 164 in 1956/7.

The film "Squirrels" was completed during the year, in co-operation with the Ministry of Agriculture, and is shortly to be released.

Various record shots of ploughing and planting were collected during the year and it is hoped to make this into a short film on the history of upland afforestation by the Forestry Commission.

Over 250 enquiries were dealt with during the year and more than 5,000 separate items of printing, developing or copying were carried out.

PART II

Research Undertaken for the Forestry Commission by Workers attached to Universities and other Institutions

RESEARCHES IN MYCORRHIZA AND SOIL MYCOLOGY

By Dr. I. LEVISOHN and M. E. PARRY
Bedford College, University of London

During 1958, work at Bedford College has concentrated on the following researches:

(1). Continuation of a microbiological analysis of certain types of nursery soils (in particular those of the agricultural type) in connection with the failure to establish, in these soils, ectotrophic mycorrhizal infection of the seedlings.

(2). Experiments with mycelia of basidiomycetes frequent in good stands of conifers in this country, and which, so far, have not been tested for their capacity of forming mycorrhizas and stimulating tree growth.

(3). Continuation of laboratory tests designed to differentiate between ecological groups of soil fungi involved in actual root infections and (or) rhizosphere effects on the higher plant.

(4). Laboratory tests for different groups of root mycelia.

(1) Activity of Certain Root-infecting Fungi in Nursery Soils of the Agricultural Type

Among the factors inhibiting the growth of certain tree species in nursery soils of high pH (mainly the agricultural type of soil), the absence or low activity of mycorrhizal mycelia has been suspected to play a role. The view has often been advanced that, by sterilization, organisms antagonistic or competitive as regards these ectotrophic mycelia are eliminated, at least for some time, from the treated soil, and that eventually the mycorrhizal fungi, in a condition of higher virulence, would re-colonize the sterilized areas. However, frequent examination of root samples from sterilization trials in nurseries and from specially designed pot-culture experiments have shown that, even 1-2 years after sterilization, ectotrophic mycorrhizas are practically absent from the seedlings under observation and that an intracellular, haustorial infection is very wide-spread in these plants.

The phenomenon that a root association believed to be mildly parasitic should be so prevalent in seedlings of good or very good quality has been puzzling for a long time. Only recently detailed cytological studies have shown that in many cases the form of haustorial infection present in these seedlings growing in sterilized soil, is not identical with the form of intracellular infection observed in sub-standard seedlings growing in the same soil not sterilized.

Roots from sterilized soils have been found to exhibit a noticeable digestion of the haustorial mycelium within the cortical cells, while digestion has not been observed in root material from the untreated soil. It does not seem unjustified to assume that the higher plant benefits from the products of digestion.

So far, no investigations have been carried out to determine whether the intracellular infection of the stimulated seedlings growing in these sterilized soils is caused by a mycelium (or mycelia) different from that (or those) forming haustoria within the roots of plants from the unsterilized soil. There is much reason to assume that the same mycelium is involved in the two forms of infection and that, in the case of the seedlings from the sterilized soil, the balance of infection has shifted in favour of the higher plant. Researches (including isolation of the haustorial mycelia) are in progress to elucidate these points.

(2) Antagonistic Effects of a Mycelium Common in Certain Nursery Soils on Various Ecological Groups of Fungi

In earlier communications (*Rep. For. Res.* 1957; *Nature*, 1957) the antagonistic influence of a strain of *Alternaria tenuis* on mycorrhizal fungi was described. Since then, antibiotic effects of this common soil fungus have been demonstrated under *in vitro* conditions on an additional number of mycelia known to be mycorrhiza-formers, e.g. *Boletus badius*, *B. luteus*. It is of interest that a certain group of mycorrhiza-formers which have been found to exercise a considerable soil activity as free-living mycelia, e.g. *Boletus subtomentosus*, *Mycelium radicis nigrostrigosum*, were indifferent to the fungistatic system of *Alternaria tenuis*.

Pot-culture experiments with pine seedlings have, so far, not given a clear picture of the relationship between *A. tenuis* and mycorrhizal mycelia in environments approximating to natural conditions. In a nursery soil of a high pH, the plants failed to show any reaction, in development and root infection, to the antagonistic strain of *A. tenuis* which had been introduced into the soil in combination with various mycorrhizal fungi of the types affected, and not affected by *A. tenuis* under pure culture conditions. However, the antagonistic mycelium was observed to have adverse effects on the growth of young pines growing in a heathland soil and, simultaneously, to decrease the incidence of mycorrhizal infection. It was further recorded that, in a growing medium from which mycorrhizal fungi were absent, i.e. sterilized sand, *A. tenuis* inhibited the growth of the seedlings. In pot-cultures with sand, the average height of Scots pine was: control—3 inches; inoculated *A. tenuis*—2 inches. Since no root infection was detected in any of these sand cultures, the influence on plant growth appears to be due, at least in this case, to a direct rhizosphere influence of *A. tenuis*. Further experiments are planned to investigate the effect of the fungus under *in situ* conditons.

As regards root fungi other than mycorrhizal mycelia, mixed cultures have shown that, in addition to pseudomycorrhizal fungi, other parasitic root associates like *Verticillium* and *Pythium* are also not affected by the antagonistic principle of *Alternaria tenuis*.

Pronounced inhibition, on a synthetic culture medium, was recorded for a number of timber-decay fungi, e.g. *Armillaria mellea*, *Fomes annosus*, *Pleurotus* *ostreatus*, *Polyporus betulinus*. In the literature of the last decade, various soil organisms have been discussed which were found to inhibit (at least under *in vitro* conditions) the growth of *Fomes annosus*, and occurrence of such organisms in the presence or absence of the root-rot fungus has been studied. In these directions, Björkman (1949), Rishbeth (1951 and later), Rennerfelt (1949-1957), Nissen (1956), and other workers have achieved valuable research relating to the *Fomes annosus* problem. It is very questionable whether investigations in connection with the observed effect of *Alternaria tenuis* on *Fomes annosus* in pure culture conditions would contribute to further the *Fomes annosus* work, but it might nevertheless be of interest to investigate the occurrence of *Alternaria tenuis* in areas not affected, and affected in different degrees, by that root-rot fungus.

(3) Growth Stimulation of Pine Seedlings by the Mycelium of Tricholoma albobrunneum, a Basidiomycete Present in Conifer Stands in the Wareham Area and Other Parts of England

The wide distribution of *Tricholoma albobrunneum* in good stands of pine species in various parts of this country suggested experiments with pure culture mycelium of this fungus which, so far, had not been known to stimulate the growth of trees.

Inoculation experiments which were carried out in soil pits (cf. *Rep. For. Res.* 1957) demonstrated an increase in the growth of Scots pine seedlings following the introduction of *T. albobrunneum*. At the beginning of the second season of growth, only very few survivors, approximately 1 inch in height, were present in the control pit, while numerous seedlings, approximately 3 inches high, were growing in the pit inoculated with *T. albobrunneum*.

From microscopic examination only, it is difficult to determine whether the mycorrhizas of the inoculated pits are actually formed by *T. albobrunneum*. (The experiments are carried out in a soil from Wareham Heath in which at least one mycorrhiza-former is present). Isolation of the mycorrhizal associate should contribute to solving this question. The possibility that the mycelium of *T. albobrunneum* may be beneficial to the plant through a rhizosphere activity, has to be taken into account.

(4) Laboratory Tests for Different Groups of Root Mycelia

It has been reported earlier (*Rep. For. Res.* 1957/58) that laboratory methods are being developed which may provide relatively quick information about certain physiological properties of isolates of root fungi, and thus serve as a short-cut to identifying certain ecological groups of mycelia.

These tests have now been successfully employed in assorting different forms (or strains) of *Boletus scaber*, a fungal species known to produce mycorrhizal infection in various tree species and to stimulate the growth of birch and Norway spruce. (During the last year, the beneficial effect of this particular strain was also recorded for *Castanea sativa*). Apparently, the various strains of *Boletus scaber* can influence seedling growth unequally, a property which reflects, in the different reactions of the mycelia, the chemical tests employed.

The tests showed also differential reactions between mycorrhizal fungi with strong, and those with less obvious, rhizosphere activities. Mycelia like *Mycelium radicis nigrostrigosum*, *Rhizopogon luteolus*, and a certain strain of *Boletus scaber*, observed to stimulate the development of certain tree species before or even without forming root associations, gave a negative reaction in a number of tests in which fungi of the other group not exhibiting a vigorous rhizosphere activity, e.g. *Boletus bovinus*, gave a positive reaction. From the results so far obtained, it would appear that fungi regarded as 'obligate' and 'facultative' mycorrhiza-formers might be roughly assorted out by the quick chemical methods which have been employed lately.

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STUDIES IN SOIL MYCOLOGY

By Dr. C. G. DOBBS, Dr. JOAN BYWATER* and D. A. GRIFFITHS

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At the end of September, 1958, Dr. Joan Bywater left Bangor to be married and her work was taken over by D. Alun Griffiths, there being sufficient overlap during which they were working together to enable the technique of assaying soils for spore germination to be standardised. As reported last year, the assay for 1957-58 showed a strong seasonal variation with complete inhibition of germination of the test spores in the summer, but a wide range of germination levels in the winter. Before leaving, Dr. Bywater carried this monthly assay of twelve different forest soil-layers far enough to show that in the wet summer of 1958 the inhibition was less complete than in the more normal summer of 1957. She also demonstrated further the effect of incubation of samples of the same twelve soils at a range of different temperatures, showing that wherever mycostasis is present at normal temperatures it is completely removed both by temperatures above blood heat and by those below freezing point. Finally, shortly before her departure, an interesting phenomenon came to light. The sterile chrome-washed sand used for controls (see 1958 *Report*) was found to retain its non-inhibiting character only when stored in clean sealed containers. When exposed to the air of the laboratory, it gradually recovered inhibiting power, the first reduction in percentage germination being detectable after one week. Such exposed sand, when plated out on nutrient agar, gave rise to bacterial colonies. This control sand, when inoculated by being mixed with one-hundredth part of its volume of untreated soil or sand, rapidly recovered its inhibiting power, usually within one week, though to an extent which varied with the soil

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PLATE 1. Edwards: Effects of different forms and amounts of basic slag and mineral phosphate on the growth of Japanese Larch, planted on blanket bog.

Upper plot on left: 4 oz. high-grade medium-soluble slag.
Upper plot on right: 2 oz. high-grade medium-soluble slag.
Lower plot on left: 2 oz. high-grade high-soluble slag.
Lower plot on right: Control—no fertilizer.

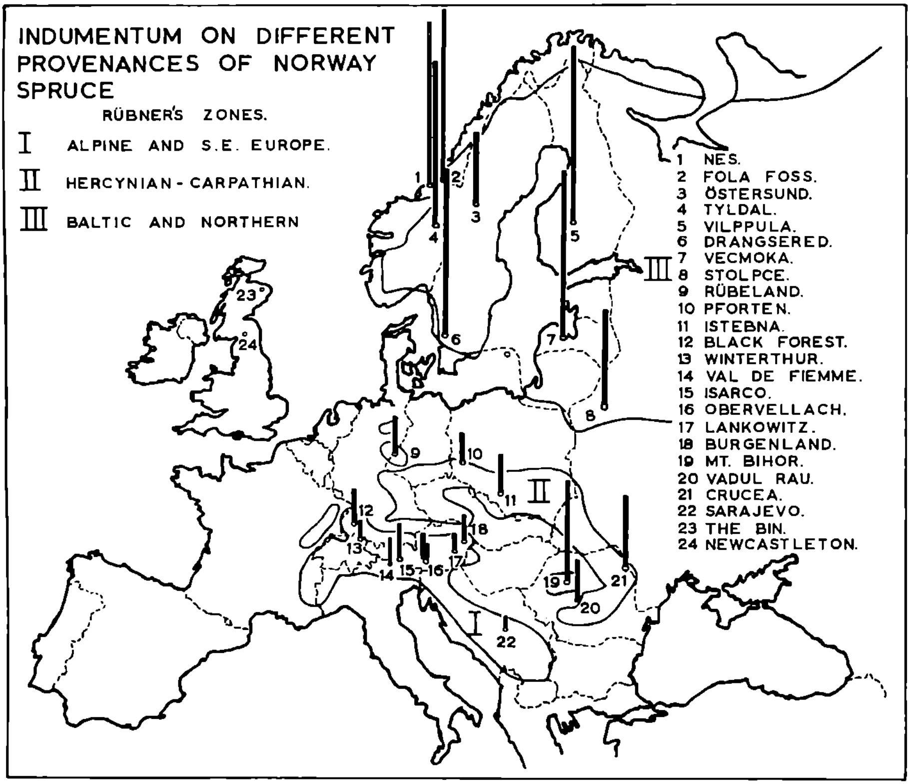

PLATE 2. Lines, Indumentum of Norway Spruce: Map of Europe showing Rübner's Zones:

I: Alpine and South-East Europe
II: Hercynian—Carpathian
III: Baltic and Northern

The mean score for each provenance is indicated by the length of the bar.

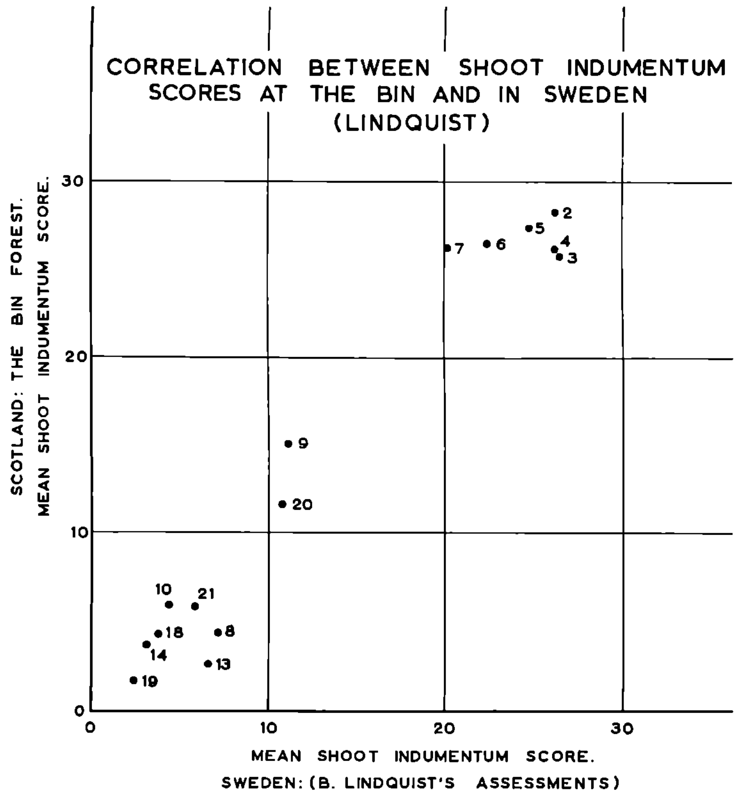

PLATE 3. Lines, Indumentum of Norway Spruce: Correlation between Shoot Indumentum. Scores at The Bin Forest, and in Sweden (Lindquist). Numbers refer to Column 2 of Table 50.

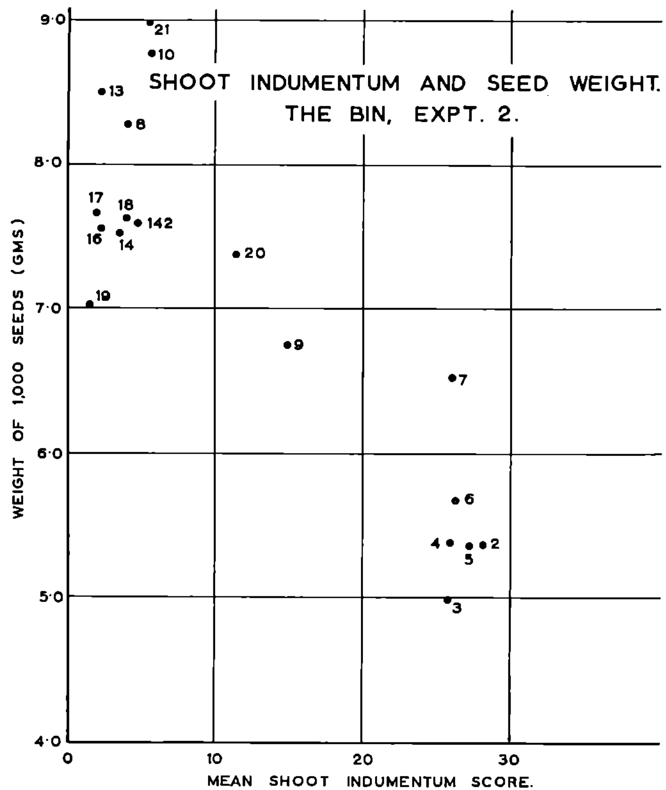

PLATE 4. Lines, Indumentum of Norway Spruce: Shoot Indumentum and Seed Weight at The Bin Forest, Aberdeenshire, Experiment 2.

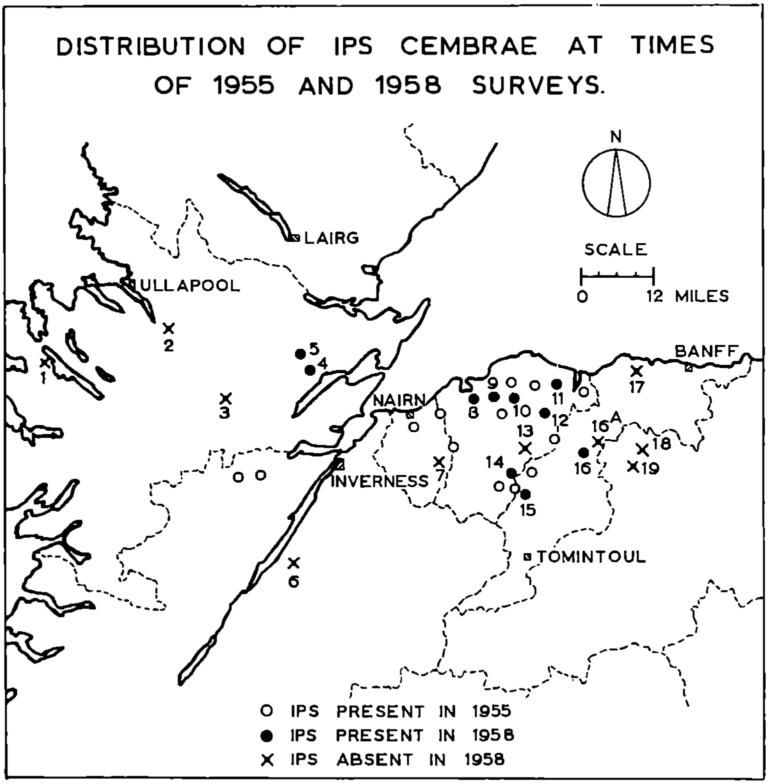

PLATE 5. Crooke and Kirkland: Ips cembrae: Distribution of Ips cembrae in North Scotland at times of 1955 and 1958 Surveys.

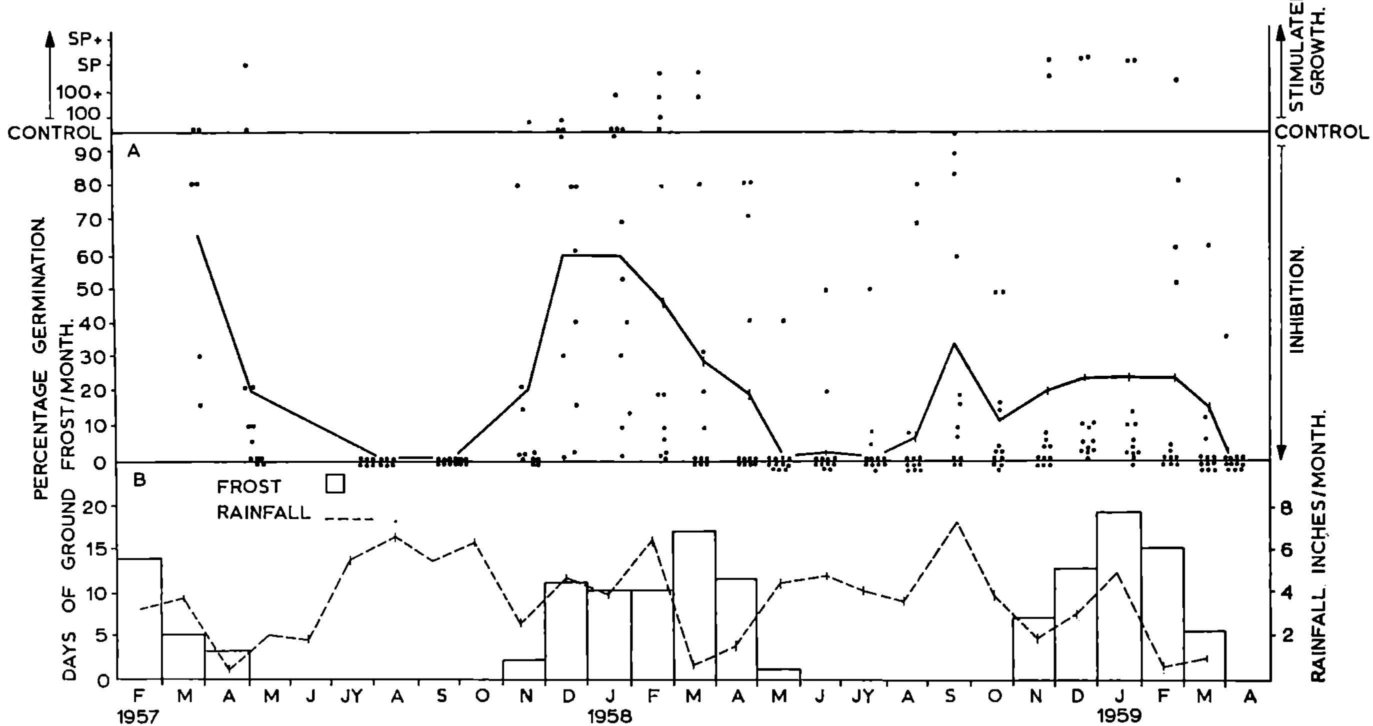

FIG. 1. A: monthly germination assay points for twelve forest soils from March 1957 to March 1959; with average shown by the bold line. Arbitrary points above 100 per cent. germination represent stimulated growth and sporing of the test fungus (*Mucor ramannianus*). B: days per month over the same period on which ground frost was recorded locally (histograms); and monthly rainfall totals (broken line).

used as inoculum, a stronger effect being obtained when nutrient (0.1 per cent malt and peptone solution) was added to the sand.

It was at this stage that the work was taken over by D. A. Griffiths, who continued it with two important additions; by attempting to relate the results of the germination assay to the weather records at a local station; and by estimating the content of available sugars in soil samples used for the assay. The results of the year's work may thus be summarised under three heads:

(1). Continuation of the monthly germination assay.

(2). Further work on the temperature relations of mycostasis.

(3). Restoration of mycostasis in control sand, and isolation of organisms which may be responsible.

(1) Continuation of the Germination Assay

Fig. 1 shows the percentage germination of spores of *Mucor ramannianus* tested at roughly monthly intervals from March 1957 to March 1959 by the method described in the 1958 *Report*. The soils used throughout were the same, namely: litter, humus and mineral samples from four sites; under beech-oak mixture, and under pine at Church Island; under beech-oak mixture and under spruce at Marian y Winllan. A collection of ten samples from the spruce site, made and assayed at the same time, showed negligible variation in the assay.

It can be seen that the seasonal variation which showed itself in 1957 was continued in 1958, but to a less marked degree. A few soils which had shown high, or stimulated, winter germination and growth, continued to support some germination during the summer, and one of these (beech-oak litter from Church Island) never fell below 50 per cent. germination even in July. These raised the average slightly above zero even in midsummer. In the following winter (1958-59) it was mainly the litter samples which gave the high germination, and stimulated growth, which in the previous winter had been found with some samples of all three layers. The mineral and humus layers gave a much lower and narrower range of germination, the assays remaining, with only two exceptions, under 20 per cent. Hence the peak of average germination for the winter of 1958-59 is much lower and flatter than that for 1957-58.

The weather records at College Farm, about a mile from Marian y Winllan, have been plotted and compared with the mycostasis levels. The most obvious relationship which shows is, of course, the broad correlation of mycostasis with seasonal temperature. The notably wet summer of 1958 differed from that of 1957 mainly in that May and June were wet, instead of dry, months, and in September the monthly rainfall total was a maximum for the two years. This sharp peak in the rainfall following a wet summer corresponds with a similar peak in the germination curve, which rises suddenly to an average level above the winter maximum, whereas in September 1957 mycostasis was still complete in all twelve soils, and maximum germination was not reached until mid-winter. The frost records show a fair correspondence between the months in which ground frost occurred, and those in which some of the soil samples showed an absence of mycostasis, and usually stimulated growth of the test fungus as compared with the controls. An exception is September 1958 in which, although there was a great reduction in mycostasis, there was no frost, and no signs of stimulated growth on the part of the test fungus. It seems reasonable therefore to attribute the effect in this month to the unusually high rainfall, and possibly to temporary waterlogging of the soil.

Sugar Content of Soils

Such climatic factors may operate in reducing soil mycostasis in two ways: by reducing the activity of the organisms which produce the inhibitor in the soil, and by liberating sugars or other carbohydrates from micro-organisms which are killed by the conditions in question. As suggested by Hinson (1954) the inhibitor appears to be of the nature of an antimetabolite competitive in its action with glucose, and the difficulty from the start has been to distinguish the effects of changes in the amount of available carbohydrates in the soil from those of the inhibitor. The first approach to this problem was to run parallel assays of soils moistened with distilled water, and with 0.1 per cent. glucose solution, and higher sugar levels where required. This served to distinguish soil samples in which the mycostatic factor is more than equivalent to 0.1 per cent. glucose, from those in which it is less. It also brought to light a number of strongly mycostatic soils which do not react to glucose, and which are assumed to possess a mycostatic factor of a different kind (see *Report on Forest Research*, 1958).

A more direct approach to the carbohydrate problem has now been undertaken by Dr. D. A. Griffiths. Water extracts of soils were obtained by bubbling oxygen-free nitrogen gas through a soil-water mixture for 20 minutes. Reducing substances, other than sugars, were precipitated with neutral lead acetate. Total reducing sugars were then estimated by Wager's (1954) modification of the Shaffer-Hartman method, and measured on a Spekker absorptiometer (see Nelson 1944). It is realised, however, that the term 'sugars' may be used here in a somewhat broad sense, and it is hoped, later, to identify the reducing substances present.

Preliminary results show a close correspondence between sugar content of soil samples and germination percentage, strongly mycostatic soils being virtually free of reducing sugars. Soil samples which, when collected, showed low mycostatic activity and high sugar content, when kept in the laboratory two to three weeks, lost their available sugars and became strongly mycostatic.

It is proposed to continue these estimations of available reducing sugars in the soil in parallel with the germination assay.

(2) **Further Work on Temperature Relations**

Fig. 2 shows the results of standard germination assays of samples of the twelve forest soils used in the seasonal assay which had been kept for ten days at a range of temperatures from —18°C to +52°C. In general, the highest points on the diagram belong to the litter layers, the lowest about equally to the humus and mineral layers. Stimulated growth including in some cases sporulation of the test fungus, as represented by points above the control level of 95 per cent. germination, occurs at both ends of the temperature range, but is more pronounced at the upper end. The whole series, repeated with the soil moistened with 0.1% glucose solution instead of water, brought to light several marked differences between both sites and soil-layers. For instance under the spruce at Marian y Winllan, mycostasis completely disappeared in all three layers even at the middle of the temperature range, but was still present in all three layers under the nearby deciduous trees at 17°C; whereas at Church Island both litters, and the pine mineral soil, reacted strongly to the glucose, but both humus samples, and the beech-oak mineral layer, did not. These differences must be assumed to reflect differences in the carbohydrate-inhibitor balance in the soils.

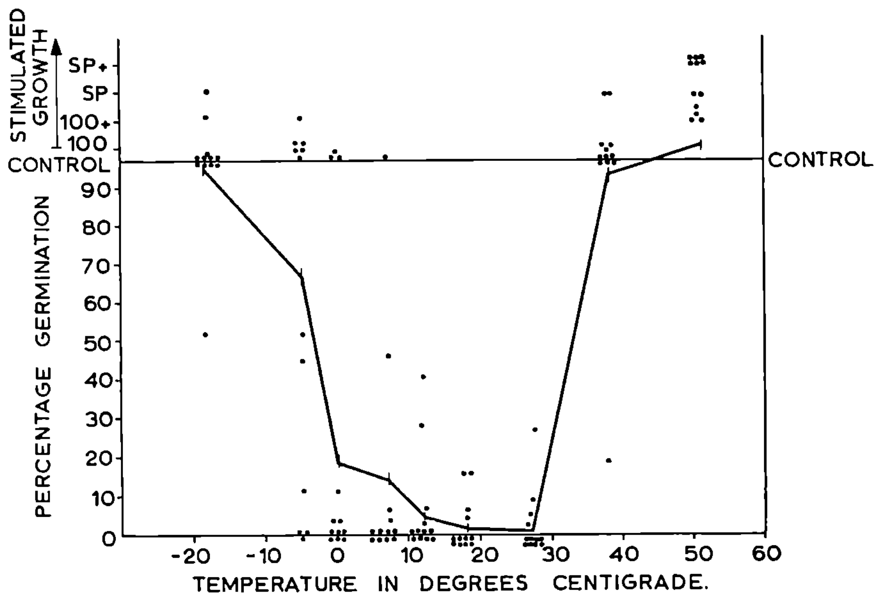

FIG. 2. Effect of temperature on mycostasis: germination assay points (details as in Fig. 1) on samples of twelve forest soils collected in May 1958 and incubated for 10 days at a range of temperatures.

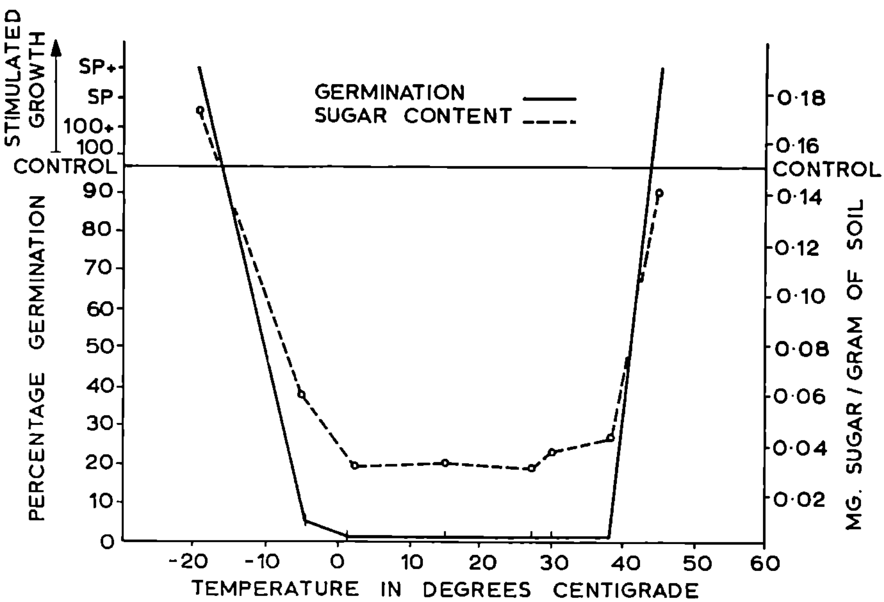

FIG. 3. Germination assay points (details as in Fig. 1) on samples of one forest soil (humus layer under pine, collected in April 1959) incubated for 8 days at a range of temperatures, with estimations of the reducing sugars in the same samples (broken line).

Fig. 3 shows a graph of the available sugar, determined by the method mentioned above, in one particular mycostatic soil (Church Island pine humus) kept for eight days at a range of temperatures. From this it appears that the main effect of extremes of temperature is the masking of mycostasis by the release of sugars from the soil. It can be seen that the amount of sugar released by the extremes of temperature used (—20°C and +45°C) was between 0.1 and 0.2 mg. per gram of soil. Autoclaving, on the other hand, released very nearly 1 mg. per gram, and it took five successive washings in warm water to remove this so as to leave an undetectable amount of sugar. This washed material lacked the stimulation of growth and sporing found upon the unwashed autoclaved sample, but showed no trace of mycostasis.

(3) Restoration of Mycostasis in Sterile Sand

It is clear that the appearance of mycostasis in sterile control sand which has been autoclaved and chrome-washed is a very different phenomenon from its reappearance in living soil incubated in the laboratory. This last seems to be due mainly to the attenuation of available sugars by micro-organisms in the soil, a process which was followed by W. H. Hinson (1954) who found that at 18°C it took thirteen days for the glucose content of a forest soil to which glucose solution had been added to fall from 2 mg./ml. of extract to a negligible quantity. In sterile washed sand, on the other hand, the appearance of mycostasis follows infection either from the air or by inoculation with untreated soil or sand. The organisms isolated in every case were bacteria. Mycostasis, as tested by a spore-bearing film pressed onto the sand, was found to occur in irregular patches, and could not be shown to spread out gradually from a central inoculum, even when a weak nutrient was added to the sand. Isolations from the centres of these patches gave seven different bacterial isolates. Colonies of these, when grown on a weak 'bacterial' agar and covered with films bearing spores of *Mucor ramannianus*, gave clear zones of inhibited germination with three of the isolates, of which one was isolated several times, and when different soils were used as inocula. The other four isolates had no such mycostatic effect. The three active isolates all proved to be Gram-negative rods, the four inactive ones were all Gram-positive.

Further Development

The work has now reached a stage at which there are too many important lines of development for all to be followed simultaneously. It had been hoped that the laborious monthly assay of spore-germination on twelve different forest soil-layers might by now have been dropped; but in view of the wide differences between the two years so far studied it is being continued, and accompanied in the current year with an estimation of the available sugar content of each soil sample. It is to be hoped that this will enable a distinction to be made between the effects of variations in available carbohydrates and in the mycostatic factor.

The next priority must be given, during the summer season of high mycostatic activity, to an attempt to make further extracts of the highly labile inhibitor, and to determine some of its characters. Only thus will it be possible to discover which, if any, of the soil bacteria produce the same type of inhibitor, and to distinguish its effects from those of competition for carbohydrates.

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SOIL FAUNA RESEARCH

By D. R. GIFFORD

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Work has been carried out on two main projects. The Ecological survey in the Forest of Ae, Dumfries, continued with the purpose of determining the differences between the fauna of the unplanted *Molinia* moorland and that of 30-year-old Sitka spruce on the same formation. It is not proposed to detail any results of these collections here, as the programme will not be completed for several months.

The second project has arisen out of the observation that many of the Oribatid mites in the samples collected seemed to be gathered in aggregations, and not distributed uniformly through what appeared to be rather uniform habitats. An experiment was devised to study the effect of distribution of fungal mycelium in Sitka spruce litter upon mite distribution, and to test the possibility of parallel variation in distribution. The basis of this experiment is to implant, in the forest, cores of litter which have been sterilized and inoculated with specific fungal mycelia, and to programme their recovery and extraction to study the recolonisation pattern of both mites and fungi.

Considerable technical difficulties are involved in all stages, and the year's work has been mainly devoted to an attempt to get reliable methods worked out. It was found that sterilization in an autoclave changed the character of the litter and disturbed the distribution of air and water in the sample. Gas sterilization was rejected since it was thought necessary to have the sample undisturbed while being treated, in an attempt to preserve the spatial structure, and not bring special influences such as compaction to bear; gas sterilization only being entirely effective with breaking up the sample to allow complete penetration. However, sterilization by gamma radiation was eventually used, and this has proved to be quite reliable provided a sufficient dosage is given. The advantages of this system are that the core extracted in its aluminium ring from the forest can be sealed in a small tin as soon as collected, to prevent drying and disturbance, and the radiation treatment can then be carried out on the tin, again without any disturbance to the sample. It is then possible to inoculate the sample in sterile conditions with a specific mycelium, and, after incubation, to return it to the forest. In addition the use of sterile cores returned direct to the forest can be used to investigate the pattern of spatial activity of both mites and fungi.

Sampling is done by using a core cutter into which are inserted aluminium rings $2\frac{1}{2}$ inches in diameter and $1\frac{1}{2}$ inches in depth. Three are used in the corer, and they are fitted into it to allow the undisturbed passage of the core as it is cut. All three are then taken out together and separated with a scalpel. Each is then immediately tinned and sealed until treated. For the ecological survey all three rings are used, and the pattern of distribution is thus observed in three $1\frac{1}{2}$ inch strata. This is not a sufficiently flexible arrangement to allow for variation in the profile being examined, and it has been found necessary to supplement this sampling with some recording of particular profile characters. The method of mite extraction is based upon a simple Tullgren funnel, but with control of temperature and humidity under the sample.

For the aggregation study a single ring is used and a core of litter extracted. This is sealed and sterilized by means of gamma radiation with a dose of $2\frac{1}{2}$M/Rads. Initially four dosages were tried to determine the efficiency of the treatment, 1, $1\frac{1}{2}$, 2 and $2\frac{1}{2}$M/Rads. In addition, some sterilized samples were left for a period of a fortnight before testing to see whether there was any tendency for recovery from the treatment. The method of testing was to take from each of the samples twelve pieces of litter and to implant these on to malt agar slopes or Yeastrol; other methods of test have not yet been carried out. In the samples tested immediately after sterilization, only one fungal growth was observed, an unidentified *Penicillium* species, probably originating from a contamination. No bacteria developed on these slopes. In the second series a number of fungi and some bacteria developed on the slopes, four fungal mycelia and three bacterial cultures appearing from samples treated with 1 M/Rad. dosage. A single *Penicillium* and one other fungal growth, awaiting identification, appeared on two samples implanted from cores given the $2\frac{1}{2}$M/Rads. dosage. The *Penicillium* may be treated as a contamination, since its origin was not near the material implanted, but the other appeared to originate actually on the litter. It will therefore be necessary to make further investigation of this particular mycelium, and to repeat the tests for sterility of high dosage cores, perhaps using different techniques.

The inoculation of sterile cores has only been done on a trial scale. Initial collections of fungi from the litter under Sitka spruce were made by the Dilution Plate technique, but as it was essential to try to isolate active fungi, those that were actually producing mycelia in the litter, this technique had to be discarded. Individual pieces of litter were collected in the forest into sterile tubes and brought into the laboratory, washed in "Chloros", and implanted on Malt Agar plates. This produced a number of mycelia, perhaps mainly those which were active in the individual needles, since other needles not washed in "Chloros" produced far more growth. Determination of these fungi is not complete.

To allow the experiment to proceed, two species, viz. a *Penicillium* species and *Trichoderma viride*, were selected and cultured. These were used to inoculate sterile cores of high dosage, to see whether they would grow. It was found at the first attempt that the *Trichoderma* had grown very little after one week, but that the *Penicillium* had grown extensively on the surface, and was producing spores. It did not in this week penetrate to the centre of the sample. The position now is, that this part of the experiment must be repeated to try and find the length of time necessary to get reasonable penetration of mycelium before returning the core to the forest for recolonisation.

It is proposed to continue this study to obtain recolonisation data regarding mites and other fungi, as the technical difficulties have been overcome to some extent. In addition it will be possible to use sterile cores to collect active fungal mycelia, as opposed to mycelia possibly originating from spores in the litter, as well as to find out how quickly various mites react to vacant territory.

As well as continuing the determination of the various species of mites collected, cultures of a few of the common species were established in porous pots. This was again an investigation of technique, as it is not intended to proceed with these cultures until they can be used to supplement field work.

FOREST SOILS RESEARCH IN SCOTLAND

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Tree Growth on Sand Dunes

Determination of height growth and foliage nutrient content of young Corsican pine, treated with inorganic fertilizers in 1954 and 1956 at Culbin Forest, Morayshire, has continued.

In the phosphate manuring experiment, the slight increase in height growth in plots treated with ground mineral phosphate in 1954 was maintained, and needle phosphate contents were significantly higher in these plots for the first time. In the N.K.Mg. factorial experiment, a very significant increase in height growth due to the nitrogen treatment was observed for the second successive year, and this effect was greater in the presence of magnesium.

The nitrogen treatment increased needle dry weight, and also needle phosphorus and potassium contents, and caused an apparent decrease in needle calcium due to a 'dilution' effect. The potash and magnesium treatments increased needle potassium and magnesium respectively; the magnesium response had not previously been detected, and was interesting in view of its effect on height growth.

Tree Growth on Deep Peat

Mr. W. O. Binns' examination of the peat under stands of lodgepole and Scots pine on deep peat at the Lon Mor, Inchnacardoch Forest, (Experiments 47. P.28 and 19. P.26) has been completed, and submitted as a thesis to the University of Aberdeen. The results may be summarised as follows:

(a) **Physical Properties.** Tree growth has dried out the peat to depths of up to eighteen inches, depending on the size of the crop; shallow draining alone has had no measurable effect except in the immediate vicinity of the drain. Vigorous trees can dry out shallow peat down to the underlying rock or moraine, and may suffer from seasonal moisture shortage later in the rotation.

There has been considerable shrinkage of the peat due to drying, resulting in the formation of underground cavities rather than a general settling of the surface.

(b) **Chemical Properties.** Lodgepole pine on the fertilized plot has removed significant amounts of potassium and inorganic phosphorus from the upper layers of the peat. No such effect was detected under the less vigorous Scots pine. Amounts of nitrogen, organic phosphorus, calcium and magnesium have not been significantly affected by tree growth. Apparent accumulation of sodium in the peat under the largest trees may be due to deposition by sea winds.

(c) **Foliage Analysis and Nutrient Deficiencies.** Diameter growth in the fertilized plots has fallen off, since 1950, in the Scots pine stand, and since 1955 in the lodgepole pine. Foliage analysis suggests that this is due to exhaustion of the applied phosphate, and also indicates incipient potassium deficiency in the largest trees.

Mineralization of Peat Nitrogen

The study of differential growth of young lodgepole pine and Sitka spruce on *deep* and *shallow* plough ridges at Wauchope Forest, Roxburghshire, has also been completed, and the results included in the above thesis. Monthly analyses during 1958 showed that the peat in the rooting zone of the deep ridges contained significantly more moisture in May, June, and July, and more ammonia-nitrogen throughout the growing season than did that of the shallow ridges. Needle nitrogen content of both tree species was higher on the deep ridges, in 1957 and 1958, than it was on the shallow ridges. The difference in height growth between the two ridge types is now, however, gradually declining. Since it has not been possible to separate completely the effects of nitrogen mineralization, moisture, and shelter on height growth, a new investigation is being started on freshly-ploughed ground.

Foliage Analyses in Existing Fertilizer Trials

Analysis of needle samples collected in October 1957 from lodgepole pine and Sitka spruce in existing Forestry Commission fertilizer experiments has been completed, and the main conclusions have been discussed in two papers (see *Emp. For. Rev.*, Vol. 38 (1) 1959, and *J. Sci. Food Agric.* Vol. 10 (12), 1959). The investigation has shown that, if allowances are made for annual variations in needle nutrient content and interactions between nutrients, it is possible to establish fairly broad ranges of major nutrient content over which growth is satisfactory, and below which a practical response to fertilizers is obtained. In some peat areas, heavier dressings of mineral phosphate are required than the normal 1½-2 ounces of Ground Mineral Phosphate per tree, and potassium deficiencies have also been observed. Nitrogen nutrition on these peats appears to be adequate if sufficient phosphate is present; liming peat at rates of up to 4 tons of ground limestone per acre has had no effect on nitrogen uptake or tree growth, but has reduced the availability of phosphate.

The study is being extended to Scots pine and Japanese larch.

Fertilizer Trials on Deep Peat

Analysis of foliage samples collected at the end of the second growing season from lodgepole pine and Sitka spruce in the N.K.Mg. fertilizer trials at the Lon Mor (Experiments 128.P.46 and 74.P.29) has established that the spruce, which had grown well as a result of repeated phosphate dressings, was suffering from acute potassium deficiency. Needle potassium content in the K. plots has risen from 0.46% to 0.67%, and needle colour has greatly improved. Needle nitrogen contents have been slightly increased by the nitrogen treatment. Diameter increment of these trees is being followed by means of vernier measuring bands.

In the lodgepole pine, the nitrogen treatment has caused an apparent reduction in needle phosphorus, calcium, and magnesium contents, and the potassium treatment has increased needle potassium content.

There have been no significant effects from the applications of ammonia, granite dust, calcium cyanamide and limestone made to young lodgepole pine in April, 1958. Low needle phosphorus values in these plots suggest that responses are being inhibited by an overall phosphate deficiency.

SUBSTANCES IN LEAVES AFFECTING THE DECOMPOSITION OF LITTER

By C. W. LOVE and B. R. BROWN

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Introduction

An investigation of leaf protein-precipitating substances in relation to work on litter decomposition and raw humus formation, as outlined in *Rep. For. Res.* 1957, has been commenced.

Since it is known that the leaves of many plant species contain a variety of polyphenolic materials, and some contain complex polyphenolic materials able to tan animal proteins, it seemed probable that the protein-precipitating materials observed in extracts of the leaves of various plant species, and especially in the leaves of those plant species giving rise to raw humus, may well be polyphenolic in nature.

Aqueous extracts of fresh *Calluna vulgaris* and *Rhododendron* material were therefore first examined for the presence of polyphenolic materials, by paper chromatography.

Results of Preliminary Investigations of Aqueous Extracts of Calluna and Rhododendron

Two-way paper chromatograms of the extracts were run, using (i) 2% acetic acid and (ii) n-BuOH/acetic acid/water 4:1:2.2 v/v, or 4:1:5 v/v (upper phase) as irrigants. The chromatograms were examined under ultra-violet light and then sprayed with one of the following reagents:

(1) Ag NO_3/NH_3

(2) Vanillin/HCl

(3) Bis-diazotised benzidine

(4) Diazotised sulphanilic acid

(5) Toluene-p-sulphonic acid

The R_F values and reactions with the sprays of the various components of the two extracts have been ascertained.

(a) Calluna vulgaris

Chromatograms have shown eleven (1-11) spots together with a streak of zero R_F in B.A.W. and R_F 0-0.5 in 2% acetic acid. The streak material was completely precipitated from the aqueous extract by the addition of excess 1% aqueous gelatine. The substances giving rise to the other spots were not precipitated by gelatine.

(b) **Rhododendron**

Chromatograms have shown thirty-six spots together with a streak, which ran to some extent in B.A.W. as well as in 2% acetic acid. The streak material was completely removed from the aqueous extract by the addition of gelatine.

It was considered that in both extracts the streak material probably represented a polyphenol of higher molecular weight than those concerned in the spots, and that this was more likely to be concerned with protein precipitation. Attention was concentrated on this, although it must be borne in mind that one or more of the materials of the other spots may well prove to be constituents of the streak material.

Attempted Isolation and Further Investigation of the Streak Material

It was thought that as the *Calluna* extract was obtained from a heterogeneous mixture of leaves and stems of varying ages, the resulting extract was unnecessarily complex. It had been hoped that as the *Rhododendron* extract was prepared from two-year-old leaves only, it would be similar, but as the above results indicate it appeared to be more complex, and therefore for all further work *Calluna* extract was used.

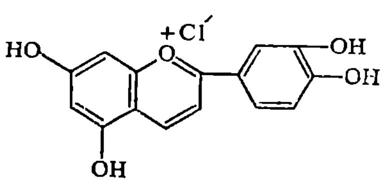
Several methods have been used in attempts to isolate the streak material from aqueous *Calluna* extract.

(a) Precipitation with gelatine.
(b) Salting out.
(c) Solvent extraction.
(d) Precipitation with ethanol.
(e) Precipitation with heavy metal salts.
(f) Column chromatography.

(a) **Precipitation with Gelatine**

1% gelatine was added to *Calluna* extract until no more precipitate appeared. The suspension was filtered, and the precipitate washed several times with water. 500 ml. of extract gave 4-5 g. of precipitate. The precipitate was leached with 50% acetone/water for 7-14 days at room temperature, and the extract filtered. The filtrate gave only a streak at the origin of a paper chromatogram, and gave a precipitate with gelatine.

On being boiled with concentrated HCl for a few minutes, the acetone/water extract developed a red colouration. This hydrolyseate, when run on paper, showed a red spot having the same R_F values as cyanidin chloride:



in two solvents.

(i) Forestal solvent $H_2O/CH_3\ CO_2\ H/HCl$ 10:30:3 (v/v)

(ii) 90% (w/v) $HCO_2\ H/3N\ HCl$ 1:1 (v/v).

R_F values of *Calluna* anthocyanidin and an authentic sample.

	Calluna cyanidin	*Authentic cyanidin*
Forestal	0.53	0.53
Formic acid/HCl	0.10	0.10

The *Calluna* cyanidin was purified on paper, and the ultra-violet spectra of the product and authentic cyanidin in 4.5% ethonolic HCl were compared.

Calluna cyanidin λ max. =547 mμ
Authentic cyanidin λ max. =548 mμ

In addition to the red spot, chromatograms of the hydrolyseate also showed a broad yellow-brown streak of high RF in both solvents. Under ultra-violet light it appeared dark brown. Nothing is yet known about its nature.

The hydrolyseate was also examined for the presence of sugars. It gave a negative result in a Molisch test. Single-way chromatograms of the hydrolyseate were run using n-butanol/acetic acid/water 4:1:5 (upper phase), or phenol as irrigant. Spraying with Ag NO_3/NH_3 or aniline hydrogen phthalate failed to detect sugars.

(b) Salting Out

It has been reported (Clark, L.M., and Levy, W. J., *J. Sci. Fd. Agric.*, (1950) 1, 213) that tannins are precipitated from aqueous solution by saturation with salt. This observation has not been confirmed in the case of *Calluna* extract but agreement with the work of Dr. W. R. C. Handley has been found.

When *Calluna* extract was saturated with salt, a dark brown solid floated to the surface. This was filtered off, washed with brine, and dried by solution in methanol and precipitation with ether. The final product was obtained as a light brown powder. The yield from 3 litres of *Calluna* extract was 2 grams. The filtrate, after standing for a few days, deposited a precipitate which sank to the bottom of the extract. This was filtered off, dissolved in methanol and precipitated with ether to give a light brown powder. The yield from 3 litres of *Calluna* extract was 2 grams. The two precipitates will be referred to as precipitate A and precipitate B respectively. The two precipitates appeared to be identical and had the following properties:

(i) They were fairly soluble in water and in methanol, sparingly soluble in ethanol or in ethyl acetate, and insoluble in ether, chloroform, benzene or light petroleum.

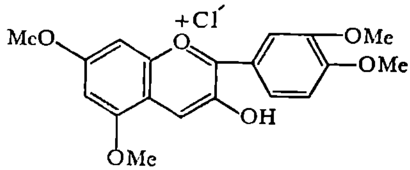
(ii) On running a two-way chromatogram of the precipitates, using (1) 2% acetic acid, (2) n-BuOH/$CH_3\ CO_2\ H/H_2O$ 4:1:5 (upper phase) as irrigants, the material appeared to stay at the origin. No other spots were detected either by examination under ultra-violet light or by spraying with diazotised sulphanilic acid.

(iii) Aqueous solutions of the precipitates did not give precipitates with gelatine; but they gave a greenish-brown turbidity with 1% ferric chloride.

(iv) When methanolic solutions of the precipitates were boiled with a few drops of conc. HCl, red colourations developed within a minute. Paper chromatograms of the hydrolyseates showed that a red compound was present, having the same R_F values as cyanidin. R_F values of hydrolysed precipitates A and B and cyanidin were:

	Precipitate A	*Precipitate B*	*Cyanidin*
Forestal solvent	0.45	0.47	0.48
Formic acid/HCl	0.095	0.095	0.085

(v) The precipitates were treated with excess diazomethane in methanol/ether/water 2:2:1 v/v at 0°C, and products were obtained, in 10% yield, which had similar appearances and solubilities to the starting materials. When these products were hydrolysed with boiling methanolic HCl, compounds having the R_F values of tetramethyl cyanidin were obtained.



R_F values of hydrolyseates and tetramethyl cyanidin were:

	Methylated A	*Methylated B*	*Tetramethyl-cyanidin*
Forestal solvent	0.90	0.91	0.89
HCO_2H/HCl	0.48	0.49	0.50
$CH_3CO_2H/2NHCl$ 3:7	0.47	0.49	0.50

These results suggest that precipitates A and B are identical and contain a leucocyanidin. The substance has not been obtained in a sufficiently pure state for further characterisation by spectroscopy and elementary analysis, and it is proposed to purify it by column chromatography for this purpose. The relative insolubility of the substance and its methyl derivative, in organic solvents, suggest that it may well be a glycoside. An attempt to isolate a sugar from the hydrolysed material as the osazone, has failed.

In view of the hypothesis that condensed tannins arise from polymerisation of leucoanthocyanins, the characterisation of this substance is important as it could prove to be a precursor of the tannin.

(c) Solvent Extraction

Calluna extract was extracted with ether for 24 hours in a liquid-liquid extractor. The ethereal extract and aqueous phase were run on two-way chromatograms using $n\text{-}BuOH/CH_3CO_2H/H_2O$ 4:1:5 (upper phase) and 2% CH_3CO_2H as irrigants. The ethereal extract contained all the compounds originally present in the *Calluna* extract, except the streak. The aqueous phase contained the streak in undiminished amount, and also traces of the other constituents.

A similar experiment was performed, extracting with ethyl acetate instead of ether, and similar results were obtained. The aqueous phase was then saturated with salt and extracted with ethyl acetate, but the streak remained in the aqueous phase. The tannin would appear to be too soluble in water to be isolable by solvent extraction.

Ether extraction of *Calluna* extract (3 litres) for 30 hours gave a brown resin (0.25 g.) which deposited at the bottom of the ethereal solution, and a gum

(1.8 g.) resulting from evaporation of the ether extract. The resin, on running on a chromatogram using 2% acetic acid as irrigant, was shown to contain a large amount of compound 1, together with a fluorescent compound which remained at the origin. The gum contained all the constituents, except the streak, compounds 1 and 7 predominating.

The gum was methylated with dimethyl sulphate and K_2CO_3 in acetone, giving two products. The first product has been characterised as a trimethoxy-napthyl-substituted aliphatic methyl ester on the following evidence:

Analysis Found: C,67.7, 67.9, H 7.1, 6.6; OMe 39.6%; M.W.324.
$C_{14}H_{10}O\ (OCH_3)_4$ requires C, 67.9; H 6.9; OMe 40.0%; M.W.318.

The ultra-violet spectrum in ethanol shows a single peak with λ max=280/ mμ, and ϵ=4,900. The infra-red spectrum shows the typical aromatic peaks, and also bands characteristic of an aliphatic ester. The second product crystallised in plates from methanol, but insufficient was obtained for analysis.

(d) Precipitation with ethanol

Calluna extract (500 ml.) was concentrated under reduced pressure in a rotary evaporator at 35°C to 40 ml., giving a clear viscous syrup. On addition of considerable excess of absolute ethanol, a pinkish brown solid was deposited, which was filtered off. The solid was soluble in water, the aqueous solution giving a precipitate with gelatine. Other constituents of the extract are also precipitated by ethanol, and this method will probably be of use only in obtaining the anhydrous tannin from a pure aqueous solution obtained by some other method e.g. column chromatography.

(e) Precipitation with lead acetate

Aqueous lead acetate was added to *Calluna* extract which had been concentrated from 500 ml. to 40 ml. in a rotary evaporator. A dirty-white precipitate formed. This was filtered off. The filtrate did not give a precipitate with gelatine. It is not yet known whether any other compounds have been precipitated, but as monomeric catechin and epicatechin are also precipitated by lead salts, it is probable that the tannin is not pure. The tannin has not yet been recovered from the precipitate, but suspension in acetic acid, followed by removal of the lead with H_2S, seems to be a likely method.

(f) Column Chromatography

The behaviour of *Calluna* extract on columns of cellulose and polycaprylamide has been studied.

A sample of concentrated *Calluna* extract was eluted from a cellulose column with n-BuOH/CH_3CO_2H/H_2O 4:1:5 (upper phase). The constituents emerged from the column in order of decreasing R_F. Separation of compounds 1, 3, 4 and 7 was not achieved, these appearing in the same fractions of eluate. There was a gap, after which compounds 2, 5 and 6 appeared together. After further elution the tannin appeared. It was not contaminated with the other constituents of the extract, but the solution was dark brown in colour, presumably due to oxidation.

The objections to the use of a cellulose column are that cellulose has a low capacity and the column is very slow-running. Thus considerable labour and time is needed to obtain even a small quantity of tannin. These difficulties have been overcome in an apparatus of Swedish manufacture in which a cellulose column of large diameter and hence high capacity is employed. A reasonable rate of elution is obtained by applying pressure to the top of the column.

Polycaprylamide has a higher capacity than cellulose and was tried as an absorbent. The *Calluna* extract was injected and eluted first with water. A brown band remained at the top of the column. When the eluate seemed to be free of phenols, as indicated by testing with diazotised sulphanilic acid, the column was eluted with 70% aqueous formamide. The brown band moved down the column, the area behind it being brownish purple. The brown band was eluted. It did not give a precipitate with gelatine. The whole of the column was then purplish.

The column was then eluted with 50% aqueous acetone, which washed out the purple substance. The eluate gave a faint turbidity with gelatine, and appeared to be a very dilute solution of the tannin.

Polycaprylamide seems to be superior to cellulose as an absorbent. It is at present only available in pellet form, and is prepared for use in a column by solution in hot phenol and precipitation with methanol. The powder obtained is extracted with methanol to remove traces of phenol, the whole operation being very time-consuming. Unless it can be obtained in powder form it is not intended to follow up the use of polycaprylamide as a means of obtaining tannins.

We thank Dr. W. R. C. Handley for helpful advice and discussions.

STUDIES ON THE PHYSIOLOGY OF FLOWERING IN FOREST TREES

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The main scope of this project was outlined in the *Research Report* for 1957, and details of some of the results obtained were given in the 1958 *Report*. The following further results have been obtained.

Effects of Photoperiodic Treatment on Flowering and Growth

Grafted material has been used in order to determine the effect of day-length conditions on flower initiation. In Scots pine, female cone formation has been shown to be dependent on long-day conditions, no cones being initiated under short-days, either in 1957 or 1958. The same appears to be true of birch. On the other hand, 4-5-year-old seedlings of lodgepole pine initiated female cones under short-days under outdoor conditions, and in fact there appears to be an actual stimulation, as compared with long-days. It is of further interest that if the short-days are given in a greenhouse at 15°-25°C, no female cones at all are formed.

In beech and Japanese larch no effects of day-length on flowering have yet been detected.

The growth of trees is also greatly affected by day-length, and it is possible by appropriate manipulation of the day-length and temperature to build up the size of grafts and seedlings at a considerable rate. For example, beech grafts have grown up to five feet in one season. In another experiment, seedling birch reached a height of 17 feet after two years under long-day conditions in a greenhouse. As was reported last year, several of these trees have borne numbers of catkins, whereas under natural conditions this would not occur for five to ten years. In addition to its value as a technique for tree-breeding, this experiment has thrown some light on the fundamental problem of the existence of juvenile and mature stages in trees. (Longman and Wareing.)

Effects of Gravity on Flowering

Further experiments have been set up to investigate the effect of tying branches of Japanese larch into different positions relative to gravity. Few flowers were initiated in 1958, due to the unfavourable weather conditions, but it is hoped that further information will be obtained in 1959. In birch, flowering is not stimulated by tying branches down; the position in *Pinus* is being further investigated.

Effect of Other Treatments on Flowering

Complete girdling of branches of 10-year-old birch has produced large numbers of female and male catkins, compared with few or none on the control branches. A similar effect has been obtained with potted seedlings in their third year. Partial breaking of the stem did not, in most cases, increase flowering, which suggests that the interruption of phloem transport is more important in this flowering effect than is the checking of the transport in the xylem.

On the other hand, Japanese larch (about 12 years old) responded to partial breaking provided the branch was also tied down. An average of 62 male flowers was formed, while only one flower was formed on all the control branches. It is also noteworthy that partial breaking and tying down had produced this result in a poor year for flower initiation, when tying down alone had little effect. Moreover, flowering was greatly increased by this treatment in a tree which was already flowering regularly, nearly 900 male and 8 female cones being formed on a single 8-year-old branch.

The effect of girdling and partial breaking is also being studied in beech and Scots pine, where the indications are that similar results may be expected.

A full-scale manurial trial was set up in 1956-7 to investigate the effects of N, P and K fertilizers on female cone production of young Scots pine. Statistical analysis of the data is still proceeding, but the main effect on female cones appears to be that potash increases both the number of cones and the proportion of trees coning. Male cones were also formed, possibly due in part to a severe drought in May and June, 1957. Nitrate and phosphate combined appear to increase considerably the proportion of trees bearing cones.

REFERENCES

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THE RELATIONSHIP BETWEEN LARCH CANKER AND THE FUNGUS TRICHOSCYPHELLA WILLKOMMII

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Freezing and Inoculation Experiments

The potted larch trees used in these experiments have been maintained in frost-proof cold frames. The trees of European larch inoculated with *Trichoscyphella willkommii* in 1953—and frozen in a refrigerator in May 1957—were "harvested" in October 1958. Anatomical examination of these trees confirmed the results of the previous visual assessments: the 1957 frost treatment, though not damaging the trees generally, had, in several cases, caused cambial damage at the periphery of the canker. Overgrowth of the cankered area was checked, and the canker reverted from a dormant to an active state, enlarging appreciably.

The batches of European larch frozen locally in 1955 or 1956, with or without subsequent inoculation, were frozen for 6 hours at —5°C in a refrigerator during the summer of 1958. Most of the trees in these experiments have been "harvested" and are being studied anatomically. Preparation and analysis of the canker sections is still in progress, but results obtained so far suggest that dormant cankers may be re-activated by subjection to frost, and that this re-activation is associated with renewed fungal activity. In some cases the initial area of frost-damaged cambium was very nearly healed by the end of the year in which the tree had been locally frozen, a canker developing the following year. A similar phenomenon in the case of trees inoculated through a slit in the bark has been noted previously.

The 1955 series included a number of trees of Japanese larch. None developed cankers, and anatomical investigation showed that in all cases the original damage had healed rapidly and completely; subsequent freezing in a refrigerator in no case caused any re-opening of the original lesion.

Spore Trapping

A Hirst volumetric spore trap, mounted on a ten-foot tower, has been installed in a badly cankered plantation of European larch, planted in 1927, in New Copse, New Forest. No information is at present available concerning the conditions under which *T. willkommii* liberates its ascospores in the field, though Mr. Beale, a student of this Department, has recently shown (undergraduate thesis, 1959) that, *in vitro*, ascospores are liberated only at 100% relative humidity, though less sensitive to temperature. The object of the spore trapping experiments is to determine whether ascospores of *T. willkommii* are present in the air when late spring and early autumn frosts occur, these being the frosts which appear to be responsible for the initiation of many cankers.

The trap was in operation from March 26th until April 19th, 1959, during which time temperature and humidity were recorded by means of a thermohygrograph placed alongside the trap. No air frost was recorded during that period, but more or less continuous records of the spore content of the air were obtained, and these are now being examined. When the trap was installed, electric power was not available, and it was operated by means of a petrol motor. A power supply is now available in the vicinity, and the trap will shortly be converted to electric operation, which will be both cheaper and more reliable than the present system. Further runs will be made this autumn and next spring.

Taxonomy

Type specimens of a number of European and North American species of Trichoscyphelloideae have been examined, and it is hoped, in the near future, to complete the examination of type or other authentic material of all such species. A key to all the species from these areas has been completed, and is being tested.

FURTHER STUDIES ON THE FUNGUS FOMES ANNOSUS

By Dr. J. RISHBETH

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Research has continued into methods of preventing air-borne infection of freshly-cut pine stumps by *Fomes annosus*. Nitrogenous applications favour growth of *Trichoderma viride* and *Penicillium* spp., which tend to suppress surface colonization by *F. annosus*; ammonium sulphamate is especially effective in this respect. Some other applications are initially toxic to stump fungi, but rapid leaching from the stump surface soon permits growth of various moulds, which again tend to suppress *F. annosus* and to a large extent other primary basidiomycete colonizers. Substances of this type include urea, which encourages growth of *Ophionectria cylindrospora*, and disodium octaborate, which favours *Botrytis cinerea*. Stumps usually die more rapidly after such treatments than after creosoting, and often as fast as untreated ones. The rapid colonization by saprophytes is advantageous when application is incomplete or the stump is subsequently damaged. The effectiveness of treatments in preventing a major spread into the stump of *Fomes annosus*, from roots already containing the parasite, is variable, and apparently depends to some extent on the particular fungus becoming dominant.

Observations have been made on rates of *F. annosus* spore deposition in plantations, and on the wider spore dispersal of this species. In relatively calm conditions, deposition rates on wood sections often exceed 20 spores/100 cm^2 /hr., close to sporophores, whilst in well-ventilated plantations, rates of 1-5 spores/hr. are commonly encountered where local spore sources occur. A simple method of trapping, in which spores are deposited on sterile muslin squares by wind, shows that *F. annosus* is a regular component of the air spora throughout Britain. Rates of catch sometimes exceed 20 spores/100 $cm.^2$/hr. near forests, and they decline with distance from source, as might be expected. Spores of *F. annosus* and other forest fungi are produced in such numbers, however, that they may still be detected over 200 miles from source. Conifer foliage often bears considerable numbers of *F. annosus* spores, as judged by examination of samples from British forests, and there is some relation between count and proximity to sporophores. These findings suggest that no area in Britain is entirely safe from stump infection by the parasite. A preliminary note on the spore-trapping method mentioned above appeared in *Nature*, 181, 1549, 1958.

RELATION OF FOMES ANNOSUS INCIDENCE TO SOIL AND FOREST MANAGEMENT IN EAST ANGLIAN PINE PLANTATIONS

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The incidence of *Fomes annosus* was studied in relation to soil characteristics and forest management over approximately 7,000 acres, mainly of Scots pine. Results, as summarized here, were derived from a study of first-rotation crops only, and apply to *Fomes annosus* as a killing rather than as a butt-rotting agent. Any damage in stands undergoing a first thinning was virtually confined to racks which had been cut through the stand some years before. Killing was closely correlated with soil reaction in the major lateral rooting zone (15-35 cm.), the critical value being pH 6. Mean losses per acre on soil with a reaction less than pH 6 did not exceed 5 cubic feet, or 1.8% of the total volume, even in third thinnings. Mean losses per acre of 35 and 31 cubic feet respectively were recorded at the third and fourth thinning in stands growing on soil with a pH greater than 7. Damage tended to be erratic in younger stands, but by the time of the third thinning (with trees about 30 years old) losses had become more consistent. Neither soil reaction at 50 cm., nor soil depth, were correlated with *Fomes annosus* losses under the conditions of this survey.

Damage was high on former agricultural land only where addition of lime had raised the soil reaction above pH 6. Where the soil reaction was less than pH 6, no difference in loss was apparent between stands on former arable and those on *Calluna*-heath. Damage was severe in many stands growing on calcareous grass-heath with a naturally high soil reaction. *Fomes annosus* infection had become stabilized by the age of 25 years in stands growing on former *Calluna*-heath. By contrast, damage was still occuring in many older plantations on alkaline soils, the maximum age of stand examined in this survey being 35 years.

Losses from *Fomes annosus* in pure stands of Corsican pine were relatively low, as compared with those in Scots pine.

SHELTERBELT RESEARCH

By R. BALTAXE
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The third three-year period of this project began in October, 1958, and coincided with a change of research workers. In consequence much of the work done to date has consisted of planning further research and making the necessary preparations. A sufficient number of shelterbelts of diverse character has been found, and owners have in all cases extended their fullest co-operation.

The long-term investigation of the silviculture of shelterbelts in the Lothians is being continued. On the two private estates where plans for the management of shelterbelts are being implemented, as on the University farms, a variety of practices is being tried. These include the planting of numerous species, in strips, blocks and groups, so disposed that at maturity belts with a variety of profiles will be formed.

Except in rare instances, neither administrative nor site conditions allow controlled silvicultural experiments to be laid down, but detailed records of conditions and operations should make the critical assessment of results possible.

Where the surrounding terrain permits wind studies to be made of shelterbelts undergoing silvicultural treatment, preparations are in hand which will enable such studies to be made periodically throughout the development of the belts. The object of this is to establish as close a correlation as possible between shelter effect and shelterbelt characteristics. For assessing exposure as a factor influencing the results of silvicultural practices, it is proposed to use the technique involving a measurement of weight lost by unhemmed flags, erected at various points within a shelterbelt.

In the context of the attempt to discover the optimum design for a shelterbelt which will have a specific sheltering effect under given site conditions, an intensive investigation of the seasonal variation of shelter afforded by deciduous and mixed belts is being undertaken. In addition, the variations in shelter due to different degrees of stocking of a shelterbelt will be studied, by progressively thinning a number of belts. The object of these investigations is to arrive at a more detailed classification of the degree of permeability of tree shelterbelts, in terms such as species composition and stocking density, which will be of practical application. The method envisaged is the preparation of the conventional curves of wind speed at various distances from a shelterbelt, supplemented by a study of the vertical wind velocity profile, particularly near the belt margins.

As this investigation will involve repeated measurements at the same points, and as these are mostly situated over agricultural land whose surface is liable to change periodically, a preliminary investigation of the effect of such changes is at present being made.

Nine sensitive cup-anemometers are available for measuring wind speed, and their relative accuracy has been checked in the field and in a wind tunnel.

These instruments are hand-operated, and in the absence of an operator for each anemometer, it is not possible to make simultaneous measurements at all points. To overcome this and other disadvantages such as the difficulty of operating the usually distant control anemometer, a simple electrical device for the remote operation of the anemometers is being designed.

The comparability of wind speed measurements on different occasions will be enhanced by having a continuous record of wind direction during the measurement periods, and an instrument to record this is being constructed.

For the measurement of the vertical wind velocity profile, it was considered desirable to use an instrument which would respond to the vertical as well as the horizontal direction components of the air stream, and to this end the use of pitot-static tubes and hot-wire anemometers has been investigated. A form of the latter, suitable for use in the field, is being designed.

RESEARCHES ON THE TANNIN CONTENT OF THE STEMBARK OF SITKA SPRUCE AND DOUGLAS FIR

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Seasonal Variation of Tannin in the Stembark of Sitka Spruce

Preliminary observations were made at Thornthwaite Forest (*Rep. For. Res.*, 1957). In a second experiment, a number of 27-year-old trees were investigated periodically from May until the following February. Each series of estimations was carried out on the butt and crown regions of the stembark of eight different trees, which grew on a site in Alice Holt Forest. The results show that in trees of this age, there is probably no significant seasonal variation in tannin content of the bark. It is probable that an increase in the tannin content of the bark tissue, with increase in age, is balanced by an increase in the (dead and living) bark tissue, with a result that the level remains without any significant variation throughout the season. The sap-streaming season is therefore *not* associated with a maximum tannin content of the bark, as has often been cited in the literature. The extract prepared from bark which is peeled during the winter months, has a more pronounced red colour (13-39 Lovibond units) than the corresponding extract (3-15 Lovibond units) from bark peeled during the season of photosynthesis and active growth. This deepening of colour is probably related to the injury inflicted by detaching the very tightly-bound bark tissue under winter conditions, and the consequent cambial polyphenoloxidase oxidation (Hathway, *Biochem., J.* 1958, *70*, 34) of the released cellular contents.

Water-soluble Tannin from the Stembark of Felled Sitka Spruce Logs

An experiment which was commenced at Alice Holt and Gwydyr Forests during the year ended March, 1957, showed that the available tannin diminished on standing, and suggested that the bark should be peeled and dried within one month of the time of felling. After this period, a marked lowering in soluble tannin is accompanied by an increase in the red colour of the corresponding extracts. These results have been substantiated in a second experiment. The fact that the non-tannin extractives diminished by one-half during the first month, suggests that an extract prepared from bark which had been allowed to stand on the felled pole for one month, would have a more favourable "tannin to non-tannin" extractives ratio than one prepared from bark detached on felling. This decrease in non-tannin extractives can probably be accounted for by the further metabolism of sugars contained in the sieve-tube system of the phloem, and this interesting biological situation merits chemical investigation.

Analysis of Douglas Fir Bark

In this experiment, the benzene-soluble wax, dihydroquercetin (taxifolin) and tannin contents of moisture-free bark were estimated. Each series of estimations was carried out on the butt and crown regions of the stembark of two dominant and two suppressed trees which grew in Alice Holt, Dalbeattie, Gwydyr, Kershope and Port Clair Forests. The tannin ranged between 5 and 22%, the wax from 3-14% and dihydroquercetin from 0.3-7.0%. In a previous study with indigenous United States trees, Kurth and Chan (*J. Amer. Leath. Chem. Ass.* 1953, *48*, 20) cite higher values for the wax and dihydroquercetin, but lower values for the tannin.

In the present work, dominant trees contain a significantly higher proportion of all three extractives than suppressed trees, and a high proportion of dihydroquercetin is associated with a high concentration of wax. The fact that the butts contain a significantly higher proportion of dihydroquercetin than the crowns, suggests a downwards translocation of this metabolite from the leaves (Hathway, *Biochem. J.* 1959, *71*, 533), and these observations accord with Hergert and Goldschmid's (*J. Org. Chem.* 1958, *23*, 700) suppositions.

PART III
Results of Individual Investigations

EFFECTS OF DIFFERENT FORMS AND AMOUNTS OF BASIC SLAG AND MINERAL PHOSPHATE ON THE GROWTH OF JAPANESE LARCH PLANTED ON BLANKET BOG

By M. V. EDWARDS

232.425.12

In 1936 and 1937 two experiments on the use of basic slag were laid down in co-operation with the Permanent Committee on Basic Slag of the Ministry of Agriculture and Fisheries.

The first experiment in 1936 was made on Sitka spruce (*Picea sitchensis* (Bong.) Carr.) which had been planted two years previously at Glenlivet Forest (Scootmore Section), Banffshire. The spruce plants were in check, and applications of fertilizer caused small beneficial effects on growth and on the colour and length of needles at first (Min. of Ag., 1937); but in the third season, though the colour and length of needles was better in the fertilized plots, there were no appreciable differences in mean height (Min. of Ag., 1939). It was recorded that, at first, ground mineral phosphate appeared more effective than basic slag. However, it became evident as time went on that the site was unsuitable for the establishment of spruce without a basal treatment such as ploughing, and the check was not caused, at least primarily, by lack of phosphate. At the age of nine years the mean height of the controls was about fourteen inches, and the mean height of the plots treated with fertilizer ranged from fourteen to twenty-three inches, with a few plots on a better site up to thirty-six inches. The differences were not significant, and the experiment was closed.

The second experiment in 1937 was made on newly-planted Japanese larch (*Larix leptolepis* (Sieb. and Zucc.) Gord.) in the Inchrigh experimental area at Glen Righ Forest in western Inverness-shire (Min. of Ag., 1937). Marked differences between the various treatments were obvious from the second year (Min. of Ag., 1939) and the experiment has continued to give valuable results. These were briefly summarised by Zehetmayr (1954, p. 69 and 70) and a photograph of part of the experiment is given in Plate 1.

Four forms of phosphatic fertilizer were compared, *viz.* high-grade high-soluble basic slag, high-grade medium-soluble basic slag, low-grade high-soluble basic slag and mineral phosphate. The high-grade slags contained about 16 per cent P_2O_5 and the low-grade about 8 per cent P_2O_5. In the high-soluble slags about 80 per cent of the P_2O_5 was soluble in citric acid, whereas in the medium-soluble ones only about 50 per cent was soluble. The mineral phosphate contained about 26 per cent P_2O_5 of a relatively insoluble nature. All the materials were as usually marketed, and ground to normal degrees of fineness.

All forms of phosphatic fertilizer were applied at three different rates, 1 oz., 2 oz., and 4 oz. per plant, and there were also control plots with no fertilizer.

Each plot contained 49 trees in a 7×7 square, spaced at 4 ft.$\times$4 ft. The outside rows of each plot were treated as a surround, and only the central 25 trees in a 5×5 plot were assessed.

The four forms of phosphatic fertilizer, each applied at three rates, together with four control plots, made a block of sixteen plots, which was replicated eight times.

Drains had been opened approximately along the contours, with just enough slope to run the water away, and from them sliced turfs were spread for planting. The fertilizer was applied beneath the turfs in the middle of March 1937 and planting was done at the end of that month. The plants were 1+1+1 transplants 12 in. to 24 in. tall, which were considered rather too large for the site. They were raised from seed obtained in Japan.

The experiment was situated on acid blanket bog (Tansley, 1939, p. 674, 676, 708), varying in depth from one-half to four feet. The blanket bog of north-west Scotland carries a varied vegetation, and though as uniform a site as possible was chosen for the experiment, three vegetation types were recognised and it was not possible to confine each block to a single type. Three blocks were sited on deep peat, averaging about three feet from surface to mineral soil, and bearing a vegetation dominated by heather, purple moor grass and bog myrtle (*Calluna vulgaris*, *Molinia caerulea*, and *Myrica gale*). Five blocks were placed on shallow peat, under one foot in depth and bearing a vegetation of deer grass and heather (*Trichophorum caespitosum* and *Calluna vulgaris*). No relationship between the growth of the trees and the depth of the peat became apparent. All the planted plots gradually developed a mixed ground flora of purple moor grass and heather.

RESULTS OF THE EXPERIMENT

Survival

None of the fertilizer applications proved harmful, and the rate of survival of the plants was almost 100 per cent at the end of the second year of growth. Deaths began to occur later, especially in the unfertilized plots, where they reached 6 per cent at the age of 10 years. These plants, without any applied phosphate, made very little growth and were evidently in a state of delicate balance between life and death, the majority making some small growth, a few dying, but the crop in general almost in a state of stagnation.

Early Height Growth

Comparison Between the Forms of Phosphatic Fertilizer. Assessment of the height of the plants and of the length of the annual shoots was made at the end

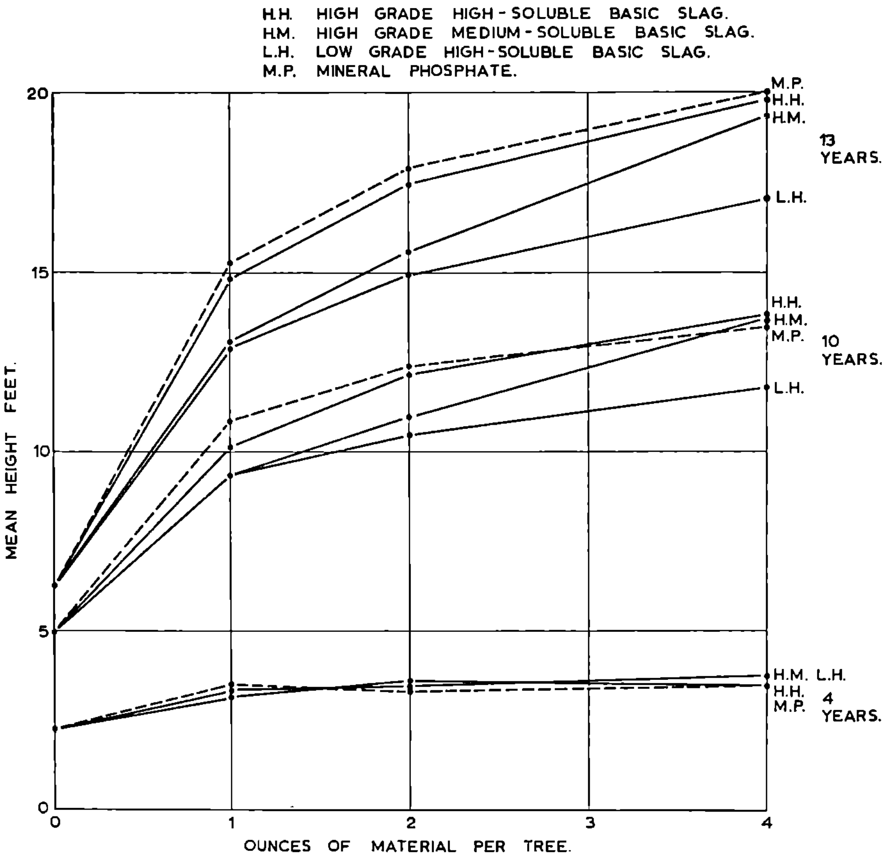

FIG. 4. Mean Height of Japanese Larch at successive ages, treated with different forms and amounts of Phosphate.

of the second year of growth, and the second height assessment was made at four years of age. Considering first the means of all the different rates at which the forms of phosphate were applied (see Table 30, col. 5), the three forms of basic slag gave better responses in shoot growth than did the mineral phosphate; but at four years the plants treated with mineral phosphate were catching up (col. 6) and the differences were not significant. It may be noted that the reverse was true in the Sitka spruce experiment referred to above, where the mineral phosphate gave the better early response; and it has not been unusual in other experiments to find that sometimes one or the other fertilizer is better, but that the differences are transient.

Comparisons Between Rates of Application. Considering the means of all the different forms of phosphate, all levels of application more than doubled the second year shoot growth of the control plants, but the differences between the three rates of application were small. At four years, the control plots averaged 2.3 ft. and those with 4 oz. of phosphate were the tallest at 3.7 ft. (Table 30, col. 6, see page 125.)

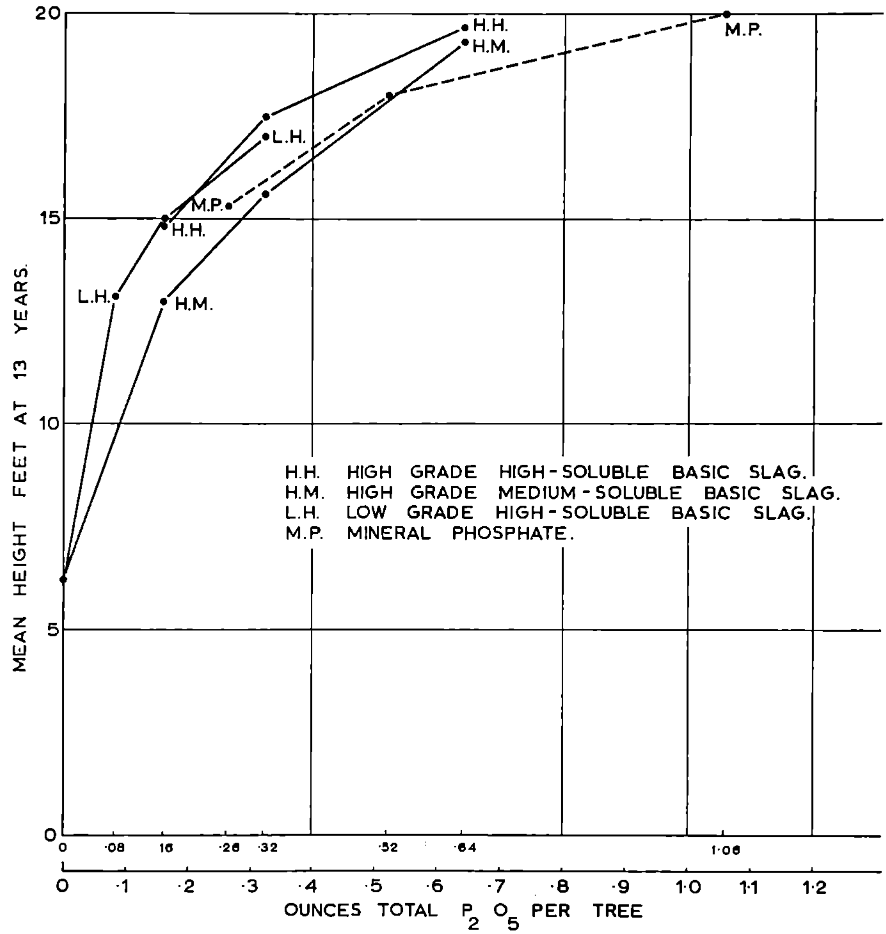

FIG. 5. Mean Height of Japanese Larch at 13 years, in relation to Total Amount of P_2O_5 supplied.

Later Height Growth

Comparisons Between the Forms of Phosphatic Fertilizers. As the plants grew the differences increased. Assessments of height were made at ten and thirteen years of age. The results are given in cols. 7 and 8 of Table 30 and are depicted in Figure 4. In terms of equal weights of fertilizer applied, by the tenth year the low-grade high-soluble basic slag was showing significantly inferior responses, as is to be expected if its value depends on its phosphate content rather than on the solubility of the phosphate. At the one-ounce and two-ounce levels, the plots treated with mineral phosphate were leading, though at the highest level of application, the high-grade high-soluble and medium-soluble basic slag treatments were in the lead (as in the earliest years). By the thirteenth year the mineral fertilizer plots were leading at all levels of application.

Comparisons Between Rates of Application. The higher rates of application gave significantly greater height growth, and all the forms of fertilizer behaved similarly in this respect. The control plots only reached a mean height of about 6 ft. in thirteen years, whereas the increasing levels of 1, 2 and 4 oz. gave mean heights of 14.1, 16.5 and 19.0 ft. respectively. The increase in height over the controls given by 1 oz. of fertilizer was therefore over 100 per cent, and the increase given by 2 oz., over the result with 1 oz., was 17 per cent. A further increase to 4 oz., or double the rate of application, increased the height attained with 2 oz. fertilizer by a further 15 per cent.

The mean height of the plots fertilized at 4 oz, was three times that of the control plots.

Basal Area

At eighteen years of age, the trees in the most advanced plots were forming canopy and approaching the crop phase. Some trees were beginning to be

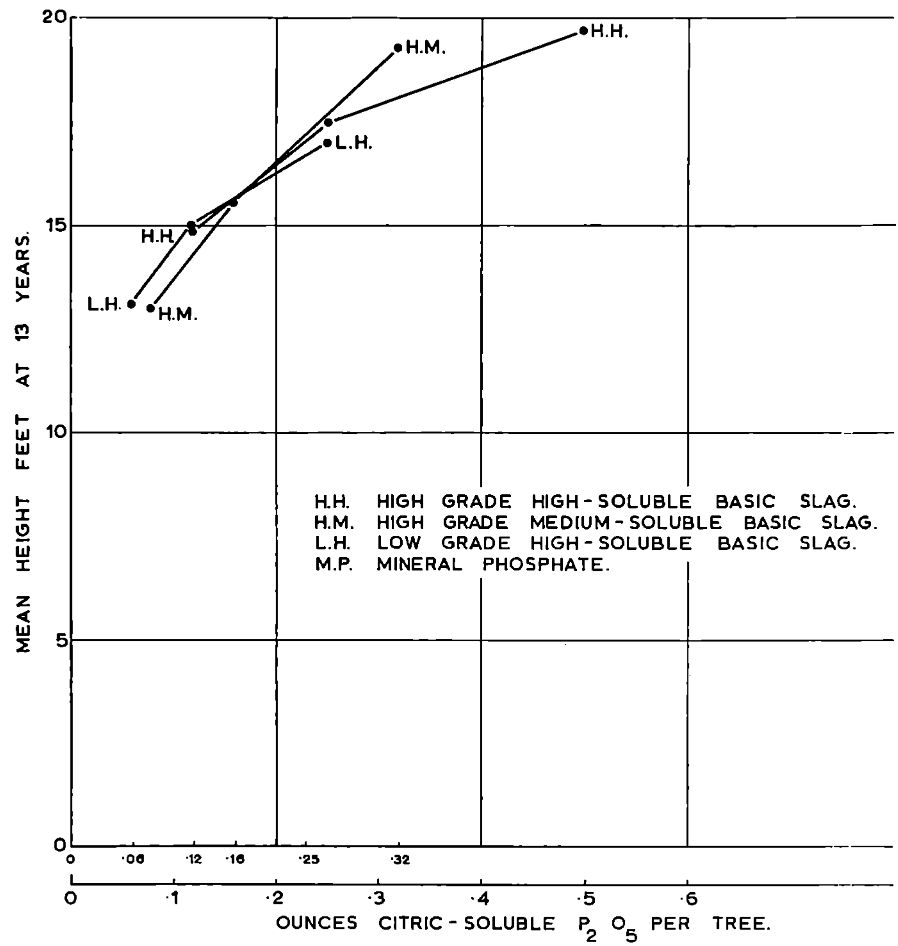

FIG. 6. Mean Height of Japanese Larch at 13 years, in relation to Amount of Citric-soluble P_2O_5 supplied.

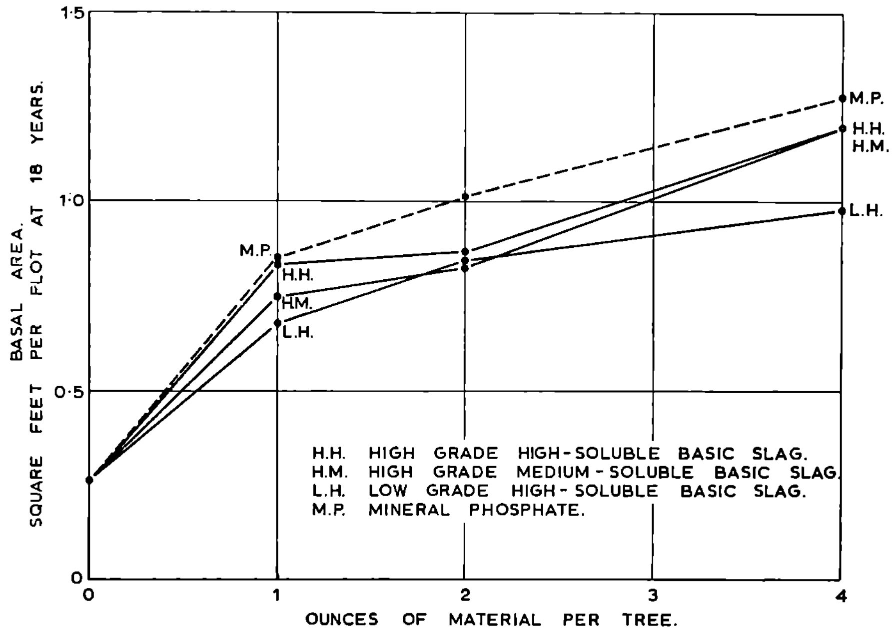

FIG. 7. Basal Area of Japanese Larch Plots at 18 years, treated with Different Forms and Amounts of Phosphate. Each Plot holds 25 trees, spaced at 4 ft. × 4 ft.

suppressed and a thinning became necessary. At this time the basal area of all the trees, both main crop and thinnings, was measured. All trees above the girth of 1 in. were included. This abnormally low limit was chosen in order to obtain basal area data from the slower-grown plots in which the plants were still small and in the individual tree phase.

The figures follow the general pattern of the height data (Table 30, col. 9, and Figure 7). The forms of fertilizer giving the largest height growth responses also show the largest responses in terms of basal area. It appears, however, that greater responses to the higher rates of application are obtained in terms of basal area than in terms of height growth. The 2 oz. rate effected an increase of 30 per cent over the 1 oz. rate, and the rate of 4 oz. an increase of 15 per cent over that of the 2 oz. level of application. The basal area of the plots fertilized at 4 oz. was four times that of the controls.

DISCUSSION

This experiment was designed to compare different forms of phosphatic fertilizers applied at different rates, and it has been shown that the differences in the response of Japanese larch to equal amounts of high-grade high- and medium-soluble basic slag and the mineral phosphate, at various levels, are small.

It is also possible to compare the fertilizers in terms of their total P_2O_5 contents, and furthermore, the different forms of basic slag can be compared in terms of the amount of P_2O_5 soluble in citric acid.

Considering first the total P_2O_5 content of the different fertilizer applications, (16 per cent P_2O_5 for the high-grade and 8 per cent P_2O_5 for the low-grade basic slag), the 2 oz. application of high-grade slag and the 4 oz. application of low-grade slag each contain 0.32 oz. P_2O_5. The mineral phosphate levels of 1, 2 and 4 oz. are equivalent to 0.26, 0.52 and 1.06 oz. P_2O_5.

These amounts of P_2O_5 have been plotted in Figure 5 in relation to the mean heights of the plots at thirteen years of age, and the data are also given in Table 28.

Table 28

Mean Height of Japanese Larch Plots Treated with 0.32 *oz.* P_2O_5 *in Different Forms of Fertilizer*

Form of Fertilizer with 0.32 oz. P_2O_5	Mean ht. of trees (ft.) at 13 years of age
2 oz. high-grade high-soluble slag	17.5
2 oz. high-grade medium-soluble slag	15.6
4 oz. low-grade high-soluble slag	17.0
4 oz. mineral phosphate (by interpolation)	15.8

At the 0.32 oz. level of P_2O_5 content, the responses given by the two high-soluble forms of basic slag were rather higher than the responses given by the high-grade medium-soluble slag and the mineral phosphate. Height growth of 17 to 17½ ft., equal to those of the high-soluble slag, would appear, from the graph, to be obtainable from about 0.4 to 0.5 oz. P_2O_5 in the form of high-grade medium-soluble slag or mineral phosphate.

In Table 29 are given the data for the 0.64 oz. level of application of P_2O_5.

Table 29

Mean Height of Japanese Larch Plots Treated with 0.64 *oz.* P_2O_5 *in Different Forms of Fertilizer*

Form of Fertilizer with 0.64 oz. P_2O_5	Mean ht. of trees (ft.) at 13 years of age
4 oz. high-grade high-soluble slag	19.7
4 oz. high-grade medium-soluble slag	19.3
4 oz. mineral phosphate (by interpolation)	18.4

At this level, the differences between the high-soluble basic slag and the lesser-soluble forms of fertilizer were not so marked. From the graph it appears that a rate of application of 1.0 oz. P_2O_5, as mineral phosphate, would give a height response of 19.7 ft., equal to that of 0.64 oz. P_2O_5 as high-grade high-soluble slag.

Taking the two levels together, it appears that the responses in the height growth of Japanese larch to highly-soluble basic slag, or to medium-soluble slag and mineral phosphate are, in terms of their contents of P_2O_5, approximately in the ratio of 1:1½. This is in agreement with the previous conclusion that equal amounts of high-grade high-soluble basic slag and mineral phosphate give approximately equal responses, as the P_2O_5 contents of these two materials are in the ratio of 1:1½.

The citric acid test is a common form of assessment of the value of basic slag in agricultural practice. This test is not applicable to mineral phosphate on account of its insolubility. In terms of citric-acid-soluble P_2O_5, the growth responses of all three forms of basic slag were closely concordant. These results are shown in Figure 6.

It is concluded therefore that high-grade high-soluble and low-grade high-soluble basic slag can be compared in terms of their P_2O_5 contents, but low-grade medium-soluble slag is less effective, rate for rate of P_2O_5. Basic slag and mineral phosphate do not give equal responses in terms of P_2O_5 content, owing to the lesser solubility of the latter material, but equal rates of application of each material as used in this experiment give comparable results, the basic slag giving better results at first and the mineral phosphate catching up and being slightly but not significantly superior at the age of twelve years. No doubt its lesser solubility is an advantage over a long length of time.

It is of interest to consider the results obtained with mineral phosphate, which is most commonly used in forest practice. The control plots have so far failed to produce a crop of trees (see Plate 1) and their surviving trees only reached a mean height of 6.2 ft. in thirteen years, which is below any recognised silvicultural Quality Class. The height attained with 1 oz. of mineral phosphate was 15.3 ft., and this is equivalent to Q.C. V. The plots receiving 2 oz. reached 18.0 ft., and this is just inside Q.C. IV. The plots with 4 oz. of phosphate reached 20.0 ft. or approximately the mean of Q.C. IV.

It has been shown that, on the average of the forms of fertilizer used, increases in the rate of application increased height growth very markedly up to 2 oz. per plant; that the increases above that rate were less in proportion to the amount applied, and that the corresponding increases in basal area were similar but possibly larger at the higher levels of application. Though it is suggested in this experiment, and has been indicated in other experiments elsewhere whose data have not yet been published, that the effect of increasing rates of application of phosphate is more marked on the basal area of a crop than on the height of the trees, this conclusion is still open to doubt. It may perhaps be an effect of the methods of measurement used, because even with the low minimum girth limit of one inch as used in this experiment, a proportion of the crop in the control plots is not measurable, whereas very few if any of the trees in the plots treated at higher levels of phosphate application fall below the limit of measurability. To avoid this possible source of error, it would be necessary to continue measurements of the plots until even the smallest tree had exceeded the minimum girth. Unfortunately it will not be possible to obtain any more data from this experiment, for the plots have inadequate surrounds and by reason of interference between plots by both crowns and roots, this experiment has had to be terminated. A new experiment with larger plots and with wider surrounds is therefore indicated for long-term trials, testing rates of 2, 4 and possibly more ounces per tree of different forms of phosphatic fertilizers, with a view to determining the effects on both height and basal area of crops throughout their lives. A study of these factors, and of the volumes of thinnings and main-crop timber produced, would enable the most suitable rate of application of fertilizers to be determined. At present a rate of 2 oz. per tree of mineral phosphate is rarely exceeded, but this experiment suggests that on blanket bog characterised before planting by heather, purple moor grass and deer grass, Japanese larch benefits from a higher rate of application.

ACKNOWLEDGMENT

These experiments were designed and the earlier data were analysed by the late Dr. E. M. Crowther, who also prepared the graphs reproduced herewith. The conclusions are based on his notes, and amplified in the light of the later assessments.

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Table 30

Basic Slag Committee's Experiment on Japanese Larch, Glen Righ Forest Expt. No. 35. P.37
Survival, Mean Height and Basal Area Data

Treatments (Means of 8 blocks)	Oz. per tree	Survival per cent		Shoot length feet 1938 (2nd season)	Mean heights in feet			Breast height basal area per plot, sq. ft. Live trees 1 in. girth and over. March, 1955, Age 18 yrs.
		Sept. 1937 (1st season)	Nov. 1946 (Age 10 years)		May 1941 4 yrs.	Nov. 1946 10 yrs.	End 1949 13 yrs.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
No phosphate (4 plots per block)	0	99	94	0.15	2.32	4.9	6.2	0.258
H.H. High-grade high-soluble basic slag	1	100	97	0.33	3.41	10.2	14.9	0.839
,, ,, ,, ,, ,, ...	2	100	97	0.41	3.58	12.2	17.5	0.866
,, ,, ,, ,, ,, ...	4	100	98	0.35	3.55	13.8	19.7	1.200
H.M. High-grade medium-soluble basic slag	1	99	99	0.34	3.18	9.4	13.0	0.747
,, ,, ,, ,, ,, ...	2	99	97	0.41	3.62	11.0	15.6	0.829
,, ,, ,, ,, ,, ...	4	99	98	0.39	3.80	13.7	19.3	1.200
L.H. Low-grade high-soluble basic slag	1	100	98	0.35	3.46	9.4	13.1	0.678
,, ,, ,, ,, ,, ...	2	99	99	0.38	3.50	10.5	15.0	0.850
,, ,, ,, ,, ,, ...	4	99	98	0.38	3.79	11.8	17.0	0.978
M.P. Mineral phosphate	1	99	98	0.32	3.46	10.9	15.3	0.846
,, ,, ,, ...	2	99	98	0.31	3.42	12.4	18.0	1.025
,, ,, ,, ...	4	100	99	0.34	3.65	13.5	20.0	1.270
S.E.	—	—	—	±0.025	±0.163	± 0.51	±0.81	±0.067
Differences for significance @ 5% level	—	—	—	0.07	0.46	1.4	2.3	0.188
Means of the data at different rates of application, for the different forms of phosphate	H.H.	100	98	0.37	3.51	12.1	17.4	0.968
	H.M.	99	98	0.38	3.53	11.4	16.0	0.925
	L.H.	99	98	0.37	3.58	10.6	15.0	0.835
	M.P.	100	98	0.32	3.51	12.3	17.8	1.047
S.E.	—	—	—	±0.014	±0.094	± 0.29	± 0.46	±0.039
Differences for significance @ 5% level	—	—	—	0.04	0.26	0.81	1.3	0.109
Means of the data for the forms of phosphate at different rates of application	0	99	94	0.15	2.32	4.9	6.2	0.258
	1	100	98	0.33	3.38	10.0	14.1	0.778
	2	99	98	0.38	3.53	11.5	16.5	0.892
	4	99	98	0.36	3.70	13.2	19.0	1.162
S.E.	—	—	—	±0.012	±0.082	± 0.25	± 0.40	±0.034
Differences for significance @ 5% level	—	—	—	0.03	0.23	0.70	1.1	0.095

SUMMARY OF RECENT RESEARCH INTO PHOSPHATE AND POTASH MANURING OF CONIFERS IN NURSERY SEEDBEDS IN SCOTLAND AND NORTHERN ENGLAND

By R. FAULKNER

Introduction

232.322.41

A sub-committee of the Advisory Committee on Forest Research was appointed in 1944 to investigate problems of nursery nutrition (Forestry Commission, 1946; p. 29). Since 1945 experimentation has been jointly carried out in England and Wales on behalf of this Committee by the Rothamsted Experimental Station staff and the Silvicultural staff of the Forestry Commission Research Branch. A summary of their findings has been published annually from 1950-56 in the *Annual Reports on Forest Research* (Crowther *et al.*, 1950-54; Benzian, 1955 and 1956).

In Scotland and northern England, nursery nutritional problems have been the subject of separate experimentation by the Silvicultural section of the Research Branch working under the guidance of the forest soils staff of the Macaulay Institute for Soil Research in Aberdeen. The northern experimental work has been of a simpler nature, and it has been based to some extent on the application of findings from the more fundamental studies of the workers in the south.

This paper describes three groups of manuring experiments which were carried out in the north during the period 1952 to 1957. The experiments were designed to provide information on the most suitable times for applying phosphatic and potassic fertilizers, and to provide data from which to decide the most suitable rates of application, mainly to Sitka spruce seedbeds, and also in some cases to seedbeds of Japanese larch, Douglas fir and western hemlock.

General Procedure

In winter, seedbeds of the usual 3½ foot width were prepared and roughly levelled. In some nurseries where partial sterilization of the soil is desirable in order to obtain 'usable' seedlings (i.e. over 1½ inches tall), the soil was partially sterilized with five gallons of 38% formalin, diluted with one hundred and fifty gallons of water, per hundred square yards.

The experiments carried out in 1952 employed a standard basal dressing of phosphate and potash at rates to provide 40 oz. of P_2O_5 and 30 oz. K_2O per hundred square yards. Superphosphate (18%-21% soluble P_2O_5) at 14 lb. or 12 lb. respectively per hundred square yards, and sulphate of potash (48½% K_2O) at 4 lb. per hundred square yards, were used in all the experiments for supplying the phosphate and potash requirements. In 1953 potash applications were raised to 40 oz. of K_2O per hundred square yards (5¼ lb. sulphate of potash) because in the previous two years potash deficiency symptoms had been frequently noticed in the needles of crops of one-year Sitka spruce seedlings. Two equal top dressings of 'Nitrochalk' (15.5% N), totalling ten pounds per hundred square yards (25 oz. N), were applied in mid and late July to supply the nitrogen requirements of the crop. The phosphate and potash fertilizers were applied at specified intervals before sowing, over plots three feet six inches square, and they were raked into the top soil. Untreated buffer strips six inches wide separated the treatments. On the date of sowing the plots were re-cultivated with a fork to a depth of three to four inches, and then raked level and rolled. The seed was sown over a central plot, three feet square, within the area treated with fertilizer; and the whole 3½-foot, square plot was covered with three-sixteenths of an inch grit cover after sowing (Faulkner, 1953). From 1952 to 1954, the rate of sowing Sitka spruce seed was five hundred and thirty *grams* per hundred square yards, i.e. eighty-five square yards per pound (Steven, 1928); but in 1955 to 1957 the sowing rate for all species was based on one thousand estimated *viable seeds* per square yard, as estimated by the tetrazolium bromide method of seed testing (Buszewicz and Holmes, 1958).

The 1952 Experiments to Compare Different Times of Application of Phosphatic and Potassic Fertilizers Before Seed Sowing

Before the commencement of these experiments, the practice was to apply fertilizers either in the form of granular compounds, or, as separate applications of superphosphate, and also of sulphate or muriate of potash, from seven to fourteen days before sowing. This time-lag was normally specified in order to allow at least a proportion of the fertilizers to form part of the soil solution. It was believed that this reduced the risk of early germinating seedlings coming into contact with local pockets of relatively high concentrations of fertilizers, which could result in damage to the plants, or, in extreme cases, death. No previous experimental work had been carried out to ascertain whether conifer seedlings are damaged by close contact with fertilizers. The author had observed in 1951 that the roots of one-year-old Sitka spruce seedlings will penetrate granules of superphosphate placed at a depth of 1½ inches below the soil, and will produce a coil of root material within the granule. This indicated that the roots produced later in the season can at least tolerate quite high concentrations of phosphate fertilizer. The same statement may not of course be equally true for a newly-formed primary root emerging from the seed.

A time-lag between fertilizer application and date of sowing results in a reduction in the length of the growing season, which in turn results in smaller seedlings (Steven, 1928). Consequently any method of extending the growing season, e.g. reduction of time-lag between fertilizer application and sowing, which will result in earlier sowing, has considerable advantages.

The Experiment

The object of the experiment was defined thus: 'To determine the effect of standard rates of application of sulphate of potash and superphosphate on the germination, growth and yield of seedlings when applied to seedbeds on the date of sowing and either left on the soil surface or cultivated into the top soil, or applied two, five or sixteen weeks before sowing'. The design of the experiment was a 6×6 Latin square.

Experimental Treatments

The first four experimental treatments were: Applications of the two fertilizers, applied together: (a) sixteen weeks before sowing, (b) five weeks before sowing,

(c) two weeks before sowing, and (d) on the date of sowing. After application the fertilizers were lightly raked into the top inch of soil, and on the date of sowing the top three to four inches of soil were thoroughly cultivated.

(e) The fifth treatment consisted of cultivating the top three to four inches of soil on the day of sowing, followed by fertilizer applications which were left on the soil surface.

(f) The sixth treatment acted as a control in which no fertilizers were applied, but it was cultivated in the same way.

The experiment was carried out at the following seven nurseries: Inchnacardoch, Inverness-shire; Quarrywood Heathland, near Elgin, Moray; Newton, Moray; Benmore, Argyll; Tulliallan, Fife; and Wykeham, Yorkshire.

Effect of the Treatments on Germination

Germination assessments based on a hundred per cent count of all seedlings in the very early stages of germination, and followed by eleven per cent systematic sample counts at fortnightly intervals during the following six weeks, showed that:

(a) Applications of fertilizer on the date of sowing which are left on the surface of the soil cause a significant ($p=0.05$) reduction in the speed of germination in its early stages. This was proved at four of the seven nurseries.

(b) Fertilizers applied on the date of sowing, and cultivated into the seedbed surface, may cause a reduction in the speed of germination in the early stages. This was proved at two of the seven nurseries.

(c) There were a few isolated instances of applications before sowing causing reductions in the speed of germination, but these were so erratic that they are not considered further.

(d) Eight weeks after germination commenced there were no appreciable differences in the numbers of seedlings between any of the treatments at any of the nurseries.

Effect of the Treatments on Yield of Seedlings at the end of the Season

None of the treatments had any significant effect on the total numbers of seedlings. (Total numbers in this paper implies *all* seedlings including the unusable seedlings, which are those too small to line-out.)

Effect of the Treatments on Height Growth of Seedlings

In comparison with the unfertilized treatment, only at one nursery were there any significant depressions in height growth caused by fertilizer applications (see Table 31). This occurred at Inchnacardoch, where the two treatments involving fertilizer applications on the date of sowing, caused a significant reduction in mean height. At all nurseries except Benmore, fertilizers left on the soil surface on the date of sowing consistently produced smaller seedlings than fertilizers which had been raked into the soil, and these differences were significant at five of the seven nurseries. The date of application of fertilizers raked into the soil rarely had any significant effect on the height growth of the seedlings.

Conclusions

These experiments showed that a time-lag between the date of fertilizer application and date of sowing does not prevent seedling mortality and is therefore unnecessary. Only the method of sowing seed in contact with the fertilizer was harmful, particularly to the speed of germination and subsequent height growth. Mixing fertilizer with the soil, followed by seed sowing on the same day, slightly retards germination but has little effect on the final heights. Time-lags between fertilizer application and date of sowing, of up to sixteen weeks, have no effect on either seedling yields or height growth.

It is concluded that in practice seed can be sown immediately after the application and cultivation of fertilizers into the top soil of seedbeds. As a result an extra seven to fourteen days of extra growth may be obtained in each growing season.

The 1953 and 1954 Experiments to Compare Different Times of Single or Combined Applications of Phosphatic and Potassic Fertilizers Before Seed Sowing

It was necessary to confirm the results from the 1952 experiments in another season, but it was considered that as the application of fertilizers at the time of sowing the seed, without cultivating the fertilizer into the top soil, had been generally harmful, it was unnecessary to repeat it. Application of fertilizers sixteen weeks before sowing was also undesirable, because of the high risk of unsuitable soil and weather conditions for bed preparation in mid-winter. The extension of the period to include autumn application of fertilizers, sometimes advocated, was also eliminated as a possibility because it has little practical value, since nursery ground is rarely cleared of plants at this time. Therefore, in 1953 the treatments were restricted to applications of fertilizers nine and three weeks before seed sowing, and on the day of sowing, together with a control without fertilizer. These four treatments were carried out with phosphate, and there were four similar treatments with potash in a 4×4 factorial experimental design.

Because germination differences had in general been so ephemeral in the 1952 experiments, no germination assessments were made. The experiment was carried out in six nurseries in 1953, and was repeated in the same form at five nurseries in 1954.

The soil from each experimental site was analysed at the Macaulay Institute, Aberdeen, for potash and phosphate content, and on the basis of the data obtained the phosphate and potash levels were classified as "low" or "satisfactory". A figure of 8 mgm. or more of both readily-soluble P_2O_5 and K_2O, per hundred grams of soil, was regarded as "satisfactory" for forest nursery soils. Figures of less than 8 mgm. per hundred grams of soil were regarded as "low". The readily-soluble phosphate and potash were extracted from the soil with 2.5 per cent acetic acid, and the phosphate was determined colorometrically (Williams and Stewart, 1941), and the potash by flame photometer. Table 32 includes a statement of the phosphate and potash contents in the various nurseries. Subsequently the growth responses of one-year seedlings to the various fertilizer treatments were compared with the initial general classification of the fertilizer levels, in order to check whether the 'satisfactory' level was in fact suitable.

The Effect of the Treatments on Yields and Mean Heights of Seedlings

The tabulation of the total number of seedlings per square yard data is presented fully in Table 33. This shows that the dates of application of either P or K fertilizers under experimentation had no significant effects on the final yield of seedlings.

Table 32 (page 137) contains the mean height data from the eleven experiments. These data show:

(a) There were only two cases where there were significant height differences between the three phosphate treatments. These occurred at Newton in 1953, where phosphate applied three weeks before sowing produced seedlings which were highly significantly taller than the remaining two treatments. The second case occurred at Benmore in 1954 where phosphate applied on the date of sowing produced a highly significant increase when compared with the "nine-weeks-before-sowing" treatment, and a significant increase in comparison with the "three-weeks-before-sowing" treatment.

(b) Positive and significant or highly significant ($p=0.01$) increases in heights were recorded in six of the eleven experiments when comparisons were made with the seedlings which did not receive phosphate.

(c) There were two cases of significant height differences between the three potash treatments. Both occurred in 1953. At Newton applications on the date of sowing produced a highly significant height increase in comparison with the "three-weeks-before-sowing" treatment, and a significant increase in comparison with the "nine-weeks-before-sowing" treatment. The reverse was the case at Benmore; applications made on the date of sowing had a highly significant harmful effect on seedling heights when compared with both the three, and the nine, weeks-before-sowing treatments.

(d) Positive and significant, or highly significant, increases in heights were recorded in only three of the eleven experiments, when comparisons were made with seedlings which did not receive potassium.

(e) Significant differences between the three "times of application" treatments were both rare and inconsistent. The reasons for the inconsistencies are not understood.

(f) Significant height responses to phosphate were recorded in six experiments (the soils of four of these had been classed initially as low in soluble P_2O_5, one was satisfactory and for one there was no data). Of the remaining five experiments, all showed some response to phosphate, although the differences were not statistically significant, (three of these sites had been classed as "satisfactory" and two as "low" in P_2O_5). Significant height increases due to potash applications occurred in three experiments, all of which had low initial soil potash levels. At a fourth nursery, where the potash content of the soil was satisfactory, potash applied three weeks before sowing resulted in a significant reduction in plant heights. In the remaining seven experiments, where there were no significant responses, three soils were initially classified as "satisfactory" for K_2O, three were "low" and for one there was no data.

Interactions between P and K Treatments

There were no significant interactions between any of the treatments at any nursery in either year.

Conclusions

Applications of both P and K fertilizers at the time of sowing, three, or, nine weeks before sowing, followed by cultivation into the top soil, are equally suitable treatments.

There are indications that the P_2O_5 and K_2O levels regarded as "satisfactory" from soil analysis data are useful guides for determinations of the requirements of phosphate and potash for conifer seedbeds.

The 1955–57 Experiments to Compare Different Rates of Application of Phosphate and Potash Fertilizers to Conifer Seedbeds

In the north the rates of application of N, P and K nutrient elements had been fixed in agreement with the staff of the Macaulay Soil Institute on the bases of (a) early experience in Scottish nurseries, and (b) some of the early work on nursery nutrition carried out in English nurseries by the Rothamsted staff. There had never been any precise experimentation in Scotland to compare the effects of different combinations of different rates of N, P and K fertilizers on conifer seedlings, and by 1953 some doubts had arisen over the adequacy of the seedbed rates for phosphate and potash, since positive responses to phosphate had been obtained in some nurseries in which a soil analysis had suggested that the phosphate levels were satisfactory. Furthermore, between 1950 and 1954, observations in other experiments in both England and Scotland gave sufficient reason to suspect that the current standard rates of fertilizers were slightly inadequate. These reasons were based on end-of-season potash deficiency symptoms, and on growth responses to high concentrations of fertilizer, e.g. in the placement of fertilizer experiments (Faulkner and Holmes, 1954). It was also believed that interactions between phosphate and potash fertilizers, when applied at differing concentrations, would provide useful clues in answering certain basic nutritional problems. For these reasons, the 1955 to 1957 series of experiments were carried out, in which it was considered necessary for two concentrations of nitrogen to be included in the experiment, so that in the event of a pronounced increase in height arising from certain combinations of P and K fertilizers, this would not be limited by inadequate nitrogen supplies. The result of the nitrogen effects in these experiments is reported on p. 145.

The experimental procedure for the 1952-54 experiments on times of applications of fertilizers was followed, except that the seed sowing density for all species was based on one thousand viable seed per square yard.

The object of the experiment was defined as : 'To compare the effect on height growth and yield of first-year conifer seedlings, of two different rates of a nitrogen fertilizer, and of three different rates of phosphate and potassium fertilizers'.

The experimental design was a 2 (nitrogen) $\times$ 3 (phosphate) $\times$ 3 (potash) factorial design.

Experimental Treatments

Superphosphate was applied at rates calculated to provide 40, 60 or 80 oz. P_2O_5 per hundred square yards (i.e. 13¾, 21 or 27½ lb. per 100 sq. yds.). Sulphate of potash was applied at rates to provide 30, 60 or 90 oz. K_2O per hundred square yards (i.e. 4, 8 or 12 lb. per 100 sq. yds.). 'Nitrochalk' was applied at rates to provide 25 or 50 oz. N per hundred square yards (10 or 20 lb. per 100 sq. yds.).

Phosphate and potash fertilizers were applied and cultivated into the top two inches of soil two weeks before seed sowing. 'Nitrochalk' was applied as a top dressing in July.

Effects of Fertilizer Treatments on Seedling Heights (See Table 34, p. 139)

(A) Phosphate

In six of the ten experiments in which Sitka spruce was sown, the 80 oz. application of phosphate was decidedly beneficial when compared with the 40 oz. (normal) application. The intermediate (60 oz.) application was generally slightly less effective. In three experiments there were no significant height differences between the three levels of application, and at one nursery (Inchnacardoch Heathland) in 1956, the 80 oz. level had a harmful effect on seedling heights.

Heavier-than-normal rates of phosphate did not produce significant height increases in either of the two Douglas fir experiments. With Japanese larch, both of the higher rates caused slight but significant height increases in one of the two experiments. No treatment had any significant effect on seedling heights in the other experiment.

(B) Potash

In one experiment, the two higher rates of application of potash had no significant good or harmful effects on the height growth of Sitka spruce, western hemlock or Japanese larch. In another Japanese larch experiment, both the higher rates (60 and 90 oz.) caused a highly significant *reduction* in seedling heights. In one of the two Douglas fir experiments, the highest (90 oz.) rate also resulted in a highly significant reduction in the seedling heights, when compared with the normal (30 oz.) rate. In the same experiment, the 60 oz. rate caused a slight but not significant reduction in height, when compared with the normal rate. In the second Douglas fir experiment there were no significant differences between the three treatments.

Interactions

There were no significant interactions between treatments.

Effects of Fertilizer Treatments on the Yield of Seedlings (See Table 35, p. 140.)

(A) Phosphate

There were only two cases where the rate of phosphate application affected the numbers of seedlings, out of the total of eighteen experiments. These were with Sitka spruce at Inchnacardoch Heathland nursery in 1955, and with western hemlock at Newton in 1957. At Inchnacardoch the 60 oz. rate of phosphate caused a highly significant increase in seedling yields. With the double rate (80 oz.) the increase was only significant at the five per cent level of significance. At Newton both of the higher rates caused a highly significant fall in the yield of seedlings.

(B) Potash

Yields of seedlings were only affected in two experiments, namely those at Benmore where both Sitka spruce and Douglas fir were sown in 1956. In the case of Sitka spruce, the yields were increased by the 90 oz. rate of application, whereas with Douglas fir both the 30 oz. and 90 oz. rates caused a highly significant *reduction* in yield when compared with the 60 oz. rates. This result is so erratic that it is presumed that the variation was due to chance causes.

Interactions

In all, there were only four significant interactions between the various combinations of treatments. These occurred in 1955 between certain $P \times K$ treatments at Wykeham, and between certain $N \times P$ and $N \times K$ treatments at Inchnacardoch. Since each interaction occurred only once in the full set of eighteen experiments, it is assumed that they were due to chance. For this reason they are not taken into further account.

Conclusion

(a) Present-day phosphate applications (40 oz. P_2O_5 per hundred square yards) are both adequate and safe to use on Japanese larch, Douglas fir and western hemlock seedbeds, but for Sitka spruce double these rates will generally produce a marked increase in height growth without any adverse effect on seedling numbers.

(b) Current rates of applications of potash (40 oz. K_2O per hundred square yards) are both adequate and safe for all four species used in the experiments.

(c) Combination treatments of high and low concentrations of nitrogen, phosphorus and potassium fertilizers, within the range of rates covered by the experiment, produced no important interaction effects on the growth or yield of seedlings of any of the species.

Discussion of the 1952 to 1957 Groups of Experiments

The experiments described have shown that it is unsafe to sow Sitka spruce seed and to leave it in contact with fertilizers. This practice delays germination and causes smaller seedlings. The factors responsible for the inhibition of germination were not determined, and are outside the scope of the study. The fact that the resulting seedlings were smaller may be accounted for by the necessarily reduced growing season resulting from delayed germination (Steven 1928). This is an arguable point because in experiments on seedbed compaction sown with Sitka spruce, it has been shown that delays in germination of up to two weeks are not associated with appreciable differences in mean heights at the end of the season (Faulkner 1957). It seems likely therefore that there was a slight but definite inhibition of growth caused by locally high concentrations of fertilizer during the early part of the year.

The development, mean height and yield of seedlings were equally good with very early applications of fertilizer, as with fertilizers applied nearer to the date of sowing, thereby indicating that loss of fertilizers by leaching is of little importance in the early part of the year.

In forest nurseries, in which at present the fertility level can be regarded as satisfactory, phosphate applications of up to double the current rates would be of benefit to Sitka spruce, but not to other species. With potash applications, however, the current rates of application seem to be optimum. It is interesting to note, however, that up to triple the current rates of potash, and double the rates of phosphate, have generally no harmful effects on conifer seedlings.

A further feature of this group of experiments was the absence of any important interactions between high and low dosage rates of the fertilizers. It is known that high levels of potash may inhibit the uptake of magnesium by plants, and magnesium deficiency symptoms were in fact recorded at Inchnacardoch where it was already known that the magnesium content of the soil was particularly low. Since, however, there were no important interactions between phosphate and potash fertilizers, it may be assumed that, within the limits of the experimental treatments, a state of unbalance in the soil between these two nutrients will not necessarily be harmful to seedling growth.

The 1953 and 1954 experiments provided an opportunity to confirm the 'satisfactory' levels of phosphate and potash in the soils, as determined by soil analysis. The indications from a limited number of comparisons between the level of P_2O_5 and K_2O in the soil, and growth responses to applications of phosphate and potash, suggest that the level which is at present regarded as satisfactory for phosphate is probably on the low side for Sitka spruce, but is satisfactory for Japanese larch, Douglas fir and western hemlock; also that the levels regarded as satisfactory for potash require no alteration for any of the species used in the experiment.

General Conclusions

Phosphate and potash fertilizers should never be left on the seedbed surface so that seed sown immediately afterwards comes into direct contact with them. If conifer seeds are sown on the day that fertilizers are applied (and there is no reason to suspect that such a practice is harmful) then the fertilizers should be thoroughly cultivated into the top few inches of soil before sowing takes place. Phosphate and potash fertilizers therefore can be applied and cultivated into the seedbed at any time from nine and probably sixteen weeks before sowing to the actual day of sowing, without harmful effect or loss of efficiency.

The present recommended basal dressing of fourteen pounds of superphosphate per hundred square yards is quite adequate for Japanese larch, Douglas fir and western hemlock seedbeds, but for Sitka spruce $1\frac{1}{2}$ to 2 times this rate will generally produce a slightly taller seedling. This may be of importance in some heathland nurseries, where the numbers of 'usable' one-year seedlings normally constitute only forty to sixty per cent of the crop, and where the phosphate content of the soil is not unduly high (8-12 mgs. P_2O_5 per 100 grams of soil).

Potash applied at the current recommended rate of four or five pounds per hundred square yards is adequate for Japanese larch, Douglas fir, Sitka spruce and western hemlock seedlings.

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Table 31

Seedling Mean Heights and Total Numbers in the 1952 Experiments on Dates of Applying P and K Fertilizers

P.K. Fertilizer Treatments	Mean Heights in Inches							Total Numbers per square yard						
	Inchnacardoch	Quarrywood	Newton	Benmore	Fleet	Tulliallan	Wykeham	Inchnacardoch	Quarrywood	Newton	Benmore	Fleet	Tulliallan	Wykeham
Applied on sowing date and left on soil surface	1.01	1.54	1.02	1.37	1.80	1.61	1.38	648	396	747	630	603	693	504
Applied on sowing date and cultivated into top 3 ins. of soil	1.01	1.70	1.17	1.34	2.03	1.88	1.58	585	459	800	702	693	720	492
Applied 2 weeks before sowing....	1.08	1.60	1.30	1.46	2.09	1.93	1.58	648	432	828	675	657	738	568
Applied 5 weeks before sowing....	1.06	1.75	1.23	1.38	2.39	1.89	1.63	666	432	747	657	675	738	601
Applied 16 weeks before sowing....	1.20	1.84	1.27	1.35	2.26	2.17	1.68	612	360	720	649	675	765	542
No P.K. fertilizers applied	1.17	1.72	1.06	1.31	2.02	1.81	1.20	603	324	783	648	639	720	542
Standard Error ±	0.04	0.06	0.04	0.04	0.07	0.04	0.05	26	37	41	36	27	29	42
Critical Differences 5%	0.12	0.19	0.11	0.12	0.21	0.13	0.15	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sight.	Not Sigt.	Not Sigt.
Critical Differences 1%	0.16	0.25	0.15	—	0.28	0.18	0.20							

Table 32

First-Year Seedling Mean Heights, in inches, in the 1953 and 1954 Experiments on Dates of Applying P and K Fertilizers

Sitka spruce

	1953						1954				
	Inch'ch. §	Newton	Benmore	Tulliallan	Fleet	Wykeham	Inch'ch. §	Benmore	Tulliallan	Fleet	Wykeham
Level of Readily Soluble P_2O_5 in nursery soils*	Low(‡)	Sat(‡)	Low(‡)	Sat(†)	Sat(†)	Low(†)	Low(‡)	Low(‡)	Sat(†)	No data(‡)	Low(†)
Treatment											
P. applied on date of sowing and cultivated into soil	2.45	2.07	2.07	1.73	3.09	1.83	1.59	2.17	1.82	1.90	1.19
P. applied 3 weeks before sowing	2.30	2.32	2.18	1.68	3.21	1.73	1.50	1.96	1.75	1.91	1.22
P. applied 9 weeks before sowing	2.45	1.92	2.32	1.61	3.06	1.80	1.59	1.91	1.89	2.03	1.20
No P. applied	1.99	1.71	1.77	1.55	3.02	1.72	1.27	1.37	1.61	1.65	1.12
SE±	0.08	0.05	0.11	0.23	0.06	0.07	0.07	0.06	0.08	0.07	0.03
Critical Differences 5%	0.25	0.16	0.33	Not Sigt.	Not Sigt.	Not Sigt.	0.12	0.16	Not Sigt.	0.21	Not Sigt.
Critical Differences 1%	0.35	0.22	—				—	0.23		0.30	
Level of Readily Soluble K_2O in nursery soils*	Low(‡)	Sat(ø)	Low(‡)	Sat(ø)	Low(†)	Low(†)	Low(ø)	Low(‡)	Sat(ø)	No data(†)	Sat(ø)
Treatment											
K. applied on date of sowing and cultivated into soil	2.34	2.14	1.81	1.60	3.15	1.78	1.36	1.94	1.76	1.91	1.16
K. applied 3 weeks before sowing	2.30	1.84	2.31	1.58	3.19	1.77	1.45	1.95	1.80	1.89	1.20
K. applied 9 weeks before sowing	2.46	1.97	2.32	1.67	3.11	1.83	1.59	1.87	1.73	1.86	1.19
No K. applied	2.10	2.07	1.90	1.70	2.92	1.71	1.54	1.65	1.75	1.81	1.19
SE±	0.08	0.05	0.11	0.23	0.06	0.07	0.07	0.06	0.08	0.07	0.03
Critical Differences 5%	Not Sigt.	0.16	0.33	Not Sigt.	0.17	Not Sigt.	Not Sigt.	0.16	Not Sigt.	Not Sigt.	Not Sigt.
Critical Differences 1%		0.22	0.46		—			0.23			

*Soil analysis data provided by the Macaulay Soil Institute, Aberdeen. The readily soluble P_2O_5 or K_2O content of soil before application of fertilizers is expressed as low (Low) or satisfactory (Sat). Height responses by the seedlings is indicated by the signs (ø) = negligible or decrease in height; (†) = slight increase in height, less than 0.3 in.; (‡) = pronounced increase in height, more than 0.3 in. §Inch'ch. = Inchnacardoch Nursery.

Table 33

Seedling Numbers per square yard, in the 1953 *and* 1954 *Experiments on Dates of Applying P and K Fertilizers*

Sitka spruce

Treatment	1953						1954				
	Inch'ch.	Newton	Benmore	Tulliallan	Fleet	Wykeham	Inch'ch.	Benmore	Tulliallan	Fleet	Wykeham
P. applied on date of sowing and cultivated into soil	1745	1027	995	1038	1142	1340	730	1396	1172	1030	1591
P. applied 3 weeks before sowing	1819	1033	986	1000	1099	1281	848	1345	1093	991	1609
P. applied 9 weeks before sowing	1956	882	934	1046	1136	1288	793	1224	1158	1003	1570
No P. applied	1643	912	934	1057	955	1278	790	1224	1139	918	1622
SE±	36	45	21	54	137	58	70	63	86	38	57
Critical Differences } 5% / 1%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.
K. applied on date of sowing and cultivated into soil	1810	1005	976	1031	1087	1220	737	1453	1278	1017	1591
K. applied 3 weeks before sowing	1804	1022	971	959	1118	1274	770	1291	1071	990	1609
K. applied 9 weeks before sowing	1735	929	919	1064	1691	1365	772	1244	1175	941	1570
No K. applied	1816	896	984	1086	1070	1328	882	1201	1037	994	1622
SE±	36	45	21	54	137	58	70	63	86	38	57
Critical Differences } 5% / 1%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.

Table 34

Seedling Mean Heights in Inches in the 1955-7 Experiments on Rates of Application of P and K Fertilizers

Treatments	1955				1956										1957			
	Sitka spruce				Sitka spruce						Japanese larch		Douglas fir		Western hemlock			
	Inch. HLN	New-ton	Bush	Wyke-ham	Inch. HLN	New-ton	Ben-more	Tull'n.	Bush	Wyke-ham	Inch.	Fleet	Ben-more	Wyke-ham	Inch. HLN	New-ton	Ben-more	Fleet
0.40 oz. P_2O_5 per sq. yd.	1.72	1.52	2.38	1.63	1.25	1.50	1.72	1.14	1.34	0.67	1.37	2.41	2.19	1.85	0.58	0.39	0.81	1.09
0.60 oz. P_2O_5 per sq. yd.	1.75	1.60	2.46	1.72	1.21	1.76	1.71	1.19	1.65	0.75	1.52	2.28	2.29	1.90	0.53	0.42	0.77	1.17
0.80 oz. P_2O_5 per sq. yd.	1.73	1.72	2.86	1.72	1.05	1.80	1.76	1.29	1.68	0.76	1.47	2.41	2.36	1.92	0.59	0.44	0.80	1.16
SE±	0.04	0.05	0.06	0.03	0.03	0.08	0.04	0.05	0.06	0.02	0.03	0.10	0.04	0.04	0.05	0.02	0.03	0.05
Critical Differences }	Not Sigt.	0.15 0.21	0.16 0.22	0.08 —	0.09 0.13	0.23 —	Not Sigt.	Not Sigt.	0.16 0.22	0.05 0.07	0.09 0.12	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt	Not Sigt.	Not Sigt.	Not Sigt.
0.30 oz. K_2O per sq. yd.	1.71	1.66	2.67	1.68	1.18	1.75	1.82	1.25	1.60	0.74	1.58	2.37	2.35	1.98	0.61	0.45	0.84	1.22
0.60 oz. K_2O per sq. yd.	1.71	1.65	2.47	1.67	1.17	1.64	1.72	1.18	1.58	0.73	1.39	2.29	2.27	1.90	0.55	0.42	0.75	1.12
0.90 oz. K_2O per sq. yd.	1.76	1.53	2.56	1.72	1.16	1.67	1.65	1.20	1.50	0.72	1.40	2.44	2.21	1.80	0.54	0.38	0.80	1.08
SE±	0.04	0.05	0.06	0.03	0.03	0.08	0.04	0.05	0.06	0.02	0.03	0.10	0.04	0.04	0.05	0.02	0.28	0.05
Critical Differences } 5% / 1%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	0.09 0.12	Not Sigt.	Not Sigt.	0.10 0.14	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.

The above data are the averages for all plots in which any particular treatments listed in the first column appears; they also include combinations with nitrogen treatments, the data for which are given on p. 156.
Inch. HLN=Inchnarcardoch Heathland Nursery.

Table 35

Seedling Numbers per Square Yard in the 1955-7 Experiments on Rates of Application of P and K Fertilizers

	1955				1956										1957			
	Sitka spruce				Sitka spruce						Japanese larch		Douglas fir		Western hemlock			
	Inch. HLN	New-ton	Bush	Wyke-ham	Inch. HLN	New-ton	Ben-more	Tull'n.	Bush	Wyke-ham	Inch.	Fleet	Ben-more	Wyke-ham	Inch. HLN	New-ton	Ben-more	Fleet
0.40 oz. P_2O_5 per sq. yd.	475	829	824	920	410	461	490	614	480	570	576	751	839	793	224	475	594	611
0.60 oz. P_2O_5 per sq. yd.	551	815	834	927	395	461	465	647	493	584	592	757	837	745	203	399	539	660
0.80 oz. P_2O_5 per sq. yd.	508	804	835	858	378	450	487	659	531	569	627	765	835	758	203	362	561	588
SE±	9	22	28	23	19	24	9	20	18	23	22	19	14	23	36	17	46	36
Critical Differences 5% / 1%	28 / 38	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	50 / 68	Not Sigt.	Not Sigt.
0.30 oz. K_2O per sq. yd.	512	858	768	885	396	426	461	648	487	580	639	740	814	771	192	420	607	603
0.60 oz. K_2O per sq. yd.	526	803	835	887	375	494	480	636	486	587	632	771	874	778	275	421	527	466
0.90 oz. K_2O per sq. yd.	496	785	799	930	411	461	499	635	530	556	570	759	823	750	162	394	560	582
SE±	9	22	28	23	19	24	9	20	18	23	22	19	14	23	36	17	46	36
Critical Differences 5% / 1%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	27 / —	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	41 / —	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.

The above data are the averages for all plots in which any particular treatment listed in the first column appears; they also include combinations with nitrogen treatments, the data for which are given on p. 156.

Inch. HLN = Inchnacardoch Heathland Nursery.

SUMMARY OF RECENT RESEARCH INTO NITROGEN MANURING OF CONIFERS IN NURSERY SEEDBEDS IN SCOTLAND AND NORTHERN ENGLAND

By R. FAULKNER

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Introduction

This article is written as a companion to the previous article on Scottish nursery experiments on phosphate and potash fertilizers.

Very briefly the history of seedbed nitrogen manuring in Scottish Forestry Commission nurseries is as follows:

From 1920 to the mid-nineteen-thirties, nitrogen was obtained from farmyard manure residues, previously cultivated into the seedbeds at the time of seedbed preparation. Rates of application were not fixed, and they varied between ten and twenty-five tons per acre, with an average of twenty tons per acre. No account was taken of the quality of the manure. Artificial nitrogen manures, for example ammonium sulphate, were seldom used during this period, although some other organic manures, principally hoof-and-horn meal or bone meal, were applied as basal dressings in some nurseries. There was little experimental work on the effects of nitrogen manuring on seedling growth at this time, and the experiments reported by Steven (1928) dealt only with comparisons of applications of humus, ashes, peat and ammonium sulphate. Neither these nor later experiments in the nineteen-thirties, using similar and other organic waste materials, produced any conclusive data, mainly because the selected manures varied in composition from year to year. Further, there were no attempts to separate the effects of the major nutrient elements P. and K. from the nitrogen effects.

From 1935-45, sulphate of ammonia was used more extensively to supplement the nitrogen in the farmyard manure. The sulphate of ammonia was usually applied as a light top dressing in mid-summer. Hoof-and-horn meal also became more fashionable during this period, but the harmful effect it had on seedling yields was not realised until examined more critically (Faulkner, 1955).

The practice of using farmyard manure in nurseries was largely abandoned by 1948, when it was realised that this type of manure was mainly responsible for the weedy condition of most nurseries. In order to provide a substitute, bulky organic composts were made to various specifications, many of which contained mixtures of hop waste, straw or bracken, with sewage sludge or dried blood as an activator. These composts were primarily intended for use in the new heathland type nurseries (Macdonald, 1954) although some were used in the older established (i.e. traditional type) nurseries on arable land. The cost of producing composts was extremely high, and some which had been poorly manufactured still contained viable weed seeds. For these reasons composts gradually went into disfavour and were abandoned by 1955. However, uncomposted hopwaste at 15 cubic feet per hundred square yards is currently used as a part source of nitrogen and other nutrients, and for maintaining fertility in many heathland nurseries.

'Nitrochalk' (a mixture of calcium carbonate and ammonium nitrate in granular form) was used after 1945. It has an almost neutral soil reaction, and is safer and easier to apply as a top dressing to conifer seedlings than is ammonium sulphate, which had been used earlier. Ammonium sulphate has a reputation for "burning" foliage, particularly if applied when the foliage is damp. Futhermore ammonium sulphate is highly deliquescent and is difficult to apply when it is damp. It has one advantage over 'Nitrochalk' when used on neutral or slightly acid soils, in that it readily dissociates in water, and the SO_4 anions are available for combining with any free Ca cations in the soil. On nursery soils with a high lime content, therefore, sulphate of ammonia applications help to locally lower the pH value of the soil by speeding up the removal of calcium. This local acidification maintains the nitrogen in the form of ammonium for a longer period of time, and slows down the rate of conversion to nitrate (Crowther and Benzian, 1953).

On the basis of observation and experience, Dr. A. B. Stewart, of the Macaulay Institute for Soil Research in Aberdeen, recommended a total application of 25 oz. of nitrogen (as an artificial quick-acting N. fertilizer) per 100 sq. yds. of seedbeds for slow-growing conifers, e.g. Sitka spruce, with lighter dressings of about half this amount for faster-growing species, e.g. larch and Douglas fir. He also recommended that this fertilizer be applied in two separate top dressings, one in early and the other in late July. Although untested in critical nursery experiments, these rates and methods have been widely used with safety since 1948 by the Forestry Commission Research Branch in Scotland.

In general practice throughout Britain, however, a lower rate of application (15 oz. N. per 100 sq. yds.) is used for top dressing one-year conifer seedbeds. This rate was suggested by the staff of the Rothamsted Experimental Station and was based on experimental evidence in England (Crowther and Benzian, 1953).

During the period 1949-51, Scottish experiments comparing 'Nitrochalk' with urea formaldehyde and formalised casein wastes, hoof-and-horn meal, fish guano and vegetable meal, indicated that the slow-acting plastics applied before sowing were equal or slightly superior to 'Nitrochalk' applied as top dressings. The other organic nitrogen manures were less effective than 'Nitrochalk', and in all cases had decidedly harmful effects on seedling yields (Faulkner, 1955). However, because supplies of plastic wastes at that time were inadequate, it was decided to continue using 'Nitrochalk' or sulphate of ammonia (on high pH soils) as the standard nursery nitrogen fertilizer.

In 1952 Leyton published the results of pot experiments on the form of nitrogen and growth of Sitka spruce seedlings in solutions of different pH values, in which he found that the form of nitrogen (NH_4) or (NO_3) had little effect on total growth, but that nitrate nitrogen stimulated better root growth than did ammonium nitrogen (Leyton, 1952). Crowther and his collaborators, on the other hand, showed that conifer seedlings prefer their nitrogen in ammonium form. (Crowther *et al*, 1954.)

In 1951 there was still a complete lack of detailed data on the effects of different rates, dates and methods of applying 'Nitrochalk' to seedbeds of Sitka spruce and other conifers. For this reason, the experiments to be described were planned, and were carried out during the period 1951-56 with the intention of obtaining additional data on these three main points.

During the period of these investigations, urea, and gaseous and liquid ammonia had been and were still being used with success in field trials by agriculturists both at home and abroad, (Andrews *et al*, 1947, Hunter and Jarvis, 1953), and the opportunity was taken to compare these two chemicals with 'Nitrochalk' as nitrogen manures. The results of these experiments are also covered in this article.

General Notes on Experimental Procedure

The experimental procedure followed the pattern described in the paper on phosphatic and potassic manuring (Faulkner, 1960).

The experimental treatments of nitrogen fertilizers were applied uniformly, by hand, over the whole 3½-foot square treatment plots. Pre-sowing applications of solid nitrogen fertilizers were sown and cultivated into the top two to three inches of soil. Liquid ammonia fertilizers were injected at a depth of four inches with a Shell 'D.D.' injector gun, using eight equidistant injection holes per 3½-foot square plot.

The 1952, 1953 and 1954 Experiments to Compare Different Methods and Times of Applying 'Nitrochalk' to Sitka Spruce Seedbeds

The Experiment

The objects of the experiment were "To compare the effects of equal total amounts of 'Nitrochalk' on conifer seedbeds, when applied either as one-third before sowing, and two subsequent dressings of one-third each in either June, July or August, or combinations of any two of these months, with two separate applications of 'Nitrochalk' as two top dressings in June, July or August or combinations of any two of these months".

The design of the experiment was a 2 (methods of application) $\times$ 6 (combinations of months) factorial, with the twelve treatments randomised in each of four separate blocks.

Experimental Treatments

'Nitrochalk' was used at rates calculated to provide 25 oz. N. per 100 square yards, i.e. approximately 10 lb. of 'Nitrochalk' per 100 square yards. The treatments themselves are defined in the object of the experiment, and they appear in list form in column 1 of Tables 36 and 37. The experiment was repeated in 1952 in the following seven nurseries. Inchnacardoch, Inverness-shire; Littleburn Heathland, Easter Ross; Newton, Moray; Benmore, Argyll; Tulliallan, Fife; Fleet, Kirkcudbrightshire and Wykeham, Yorkshire. In 1953 the experiment was repeated at Littleburn, Newton, Benmore, Tulliallan and Wykeham. In 1954 it was again repeated at the same nurseries, with the exception that Inchnacardoch established nursery was substituted for Littleburn Heathland nursery (see pp. 154 and 155).

Effect of the Treatments on the Height Growth of Seedlings

When comparing the two *methods* of application, namely, applications *entirely* as a top-dressing, or, applications in which one-third was applied before sowing with the *residue* as top dressing in midsummer, it was found that only five out of the total of seventeen experiments produced any significant ($p=0.05$) differences between the two treatments (see Table 36). In 1952 at Inchnacardoch and Fleet, the method in which the fertilizer was applied entirely as top dressing caused a marked and highly significant (p=0.01) reduction in seedling heights, in comparison with the method in which one-third of the 'Nitrochalk' was applied before sowing. The exact opposite occurred at Benmore and Tulliallan in 1953, and again at Benmore in 1954, although the differences were only significant at the five per cent level of significance. A general trend was unobtainable from the data, since in eight of the seventeen experiments one method produced the tallest seedlings, in another eight experiments the reverse was true, and in the remaining experiment the effects were equal.

The month of application of 'Nitrochalk' had an appreciable and significant effect on seedling heights, in nine of the seventeen experiments. Details are given in Table 36, from which it can be seen that applications of 'Nitrochalk' in June are generally the least effective. July applications gave an improvement in growth when compared with June applications, while the combination of July and August, or "August only", applications were usually the most successful.

Effect of the Treatments on the Yield of Seedlings

Table 36 gives the full details of the seedling yield data. Significant differences between treatments are rare in the whole set of seventeen experiments. Where the differences between treatments are significant, the reasons are inexplicable, and are inconsistent in the different nurseries concerned. The overall conclusion therefore is that no treatment had any practical harmful or beneficial effect on seedling yields.

Effect of Treatments on Early Frost Damage

There were no records of differential frost damage between treatments, from the whole group of seventeen experiments, and it is therefore inferred that nitrogen applications at the rates used in these experiments are perfectly safe even when applied as late in the growing season as August.

Interactions

There were no significant interactions between the method of application, or time of application, treatments for either seedling mean heights or for yields.

Conclusions

These experiments showed that no general advantage is obtained from applying one-third of the annual dressing of 'Nitrochalk' to seedbeds before sowing. Applications of 'Nitrochalk' in June are usually less effective for increasing height growth than are applications made in July or August; there are strong indications that August applications are slightly more effective than July applications.

'Nitrochalk' at ten pounds per hundred square yards had no harmful effects on seedling yields, and it can be considered to be a safe fertilizer when applied to seedbeds by either of the two methods described and within a range of dates from June to and including August.

Applying nitrogen during the period June to August did not increase the frost susceptibility of the seedlings.

The 1955 to 1957 Experiments to Compare Different Rates of Application of 'Nitrochalk' to Sitka Spruce, Japanese Larch, Douglas Fir and Western Hemlock Seedlings

The Experiment

During the period 1955 to 1957, eighteen experiments were carried out in which were determined the effects of two rates of nitrogen, three rates of phosphate, and three rates of potash on the height growth and yield of Sitka spruce, Japanese larch, Douglas fir and western hemlock seedlings. These experiments were described in an earlier paper (Faulkner, 1960), but only the data dealing with phosphate and potash effects were presented and discussed. The nitrogen data is presented separately in Tables 38 and 39 of this article. (See p. 156.)

'Nitrochalk' was used in the experiments, and two rates of application were tested. These were 25 oz. N. per hundred square yards and 50 oz. N. per hundred square yards (i.e. 10 and 20 lb. 'Nitrochalk' per hundred square yards respectively).

Effect of the Treatments on Seedling Heights

In nine of the ten experiments in which Sitka spruce was used as the indicator species, there were no significant differences between the two concentrations of 'Nitrochalk'. At the remaining nursery, the "50 oz. N. per hundred-square-yards" treatment produced seedlings which were significantly smaller than seedlings raised with half this amount of nitrogen. At both nurseries where Japanese larch and Douglas fir seedlings were grown, doubling the normal rate of nitrogen produced a small but highly significant height increase. A slight but significant height response to the double rate of nitrogen was obtained at two out of four nurseries where western hemlock was sown. Growth of the hemlock was poor, presumably due to the unfavourable growing season in 1957.

Effects of Fertilizer Treatments on the Yield of Seedlings

Doubling the normal (25 oz.) rate of 'Nitrochalk' resulted in a highly significant reduction in western hemlock seedling yields at two of the four nurseries where the species was sown, and a significant reduction in Sitka spruce seedlings at Inchnacardoch heathland nursery in 1955. At Bush nursery, where Sitka spruce was also sown, the double rate caused a significant increase in the seedling numbers. There were no significant differences in seedling yields between the two concentrations of 'Nitrochalk' in any of the other experiments.

Conclusions

'Nitrochalk' applied at ten pounds per hundred square yards (25 oz. N. per hundred square yards), as two top dressings in July, is quite adequate for crops of one-year Sitka spruce, Japanese larch, Douglas fir and western hemlock, although some slight extra growth responses can be obtained with Japanese larch and Douglas fir by doubling this rate. Double the normal rate of application has had no pronounced adverse or beneficial effects on the final yield of Sitka spruce, Douglas fir or Japanese larch, but with western hemlock there may be a danger of lowering the yield of seedlings by high application rates. This requires confirmation.

The 1955 and 1956 Experiments to Compare Different Dates and Rates of Application of 'Nitrochalk' to Scots Pine, Japanese Larch and Douglas Fir Seedlings

The Experiment

The experimental object was "To determine the effect of 'Nitrochalk' at five, ten, or fifteen pounds per hundred square yards, applied in two equal top dressings in June, July or August, on the height growth and yield of one-year-old Scots pine, Japanese larch or Douglas fir seedlings".

The experimental design was a 3 (rates of fertilizer) $\times$ 3 (dates of application) factorial, in four randomised blocks. The sowing rate was one thousand estimated viable seeds per square yard, for all three species.

The experiment was carried out in 1955 and 1956, using Scots pine as the indicator species at Inchnacardoch, Tulliallan and Wykeham; Japanese larch at Newton, Wauchope (Roxburgh), and Bush (Midlothian), and Douglas fir at Benmore and Fleet. In all there were thirteen experiments in the series.

Experimental Treatments

The experimental treatments are defined in the "Objects" of the experiment.

Rates of applying 'Nitrochalk' at five, ten or fifteen pounds, all per hundred square yards, are equivalent to twelve-and-one-half, twenty-five and thirty-seven and-one-half ounces of N. per hundred square yards respectively. The first top dressing of 'Nitrochalk' was applied at the end of the first week of the month and the second dressing was applied at the beginning of the fourth week of the month.

Right up to the time of this series of experiments, the usual rate of application of 'Nitrochalk' to Scots pine, Japanese larch and Douglas fir seedbeds was five pounds per hundred square yards, applied in two equal top dressings in July.

Experimental Results

(See Tables 40 and 41, pp. 157 and 158)

(A) Scots Pine

In three of the five experiments, June applications produced the smallest seedlings when compared with July and August applications; at one of the two remaining nurseries the differences between treatments were so small that the data were not analysed. At the fifth experiment, at Wykeham in 1955, the June treatments produced the tallest plants. The reason for this may be the result of a prolonged summer drought which extended from late June to late August, with the consequence that the fertilizer remained on the bed surface for a long period before being washed into the soil by rain. July and August treatments were in fact synonymous at Wykeham, and this may account for the taller plants in the June treatments.

The increases in height of the July and August applications, when compared with June applications, was significant at Tulliallan in 1956, and the increased height of seedlings in the August treatment, over both the June and July treatments, was significant at Wykeham in 1956.

Rate of application of 'Nitrochalk' had no appreciable effect on seedling heights at Inchnacardoch in 1955, nor at Wykeham in 1956. At Wykeham in

1955, and at Tulliallan in 1957, the heaviest dosage (37½ oz. N./sq. yd.) of 'Nitrochalk' produced seedlings which were significantly taller than seedlings grown with the lowest rate of application (12½ oz. N.). The 1955 Tulliallan data were inexplicably erratic.

No treatment had any effect on the seedling numbers, except in 1956 at Wykeham, where June applications resulted in a significant reduction in the number of plants compared with either the July or August treatments. Cutworm damage was reported from this centre, and the yield data may be unreliable.

There were no interactions between any of the treatments which affected either seedling heights or yields.

(B) Japanese Larch

Application in different months produced very conflicting data, from which it is impossible to obtain a trend. At Newton in 1955 the June applications produced decidedly taller plants than did the July and August treatments. In the same year at Wauchope the opposite occurred. At Benmore in 1956 progressively later applications of 'Nitrochalk', from June to August, produced correspondingly taller seedlings, whereas at Bush the July applications produced much taller seedlings than the June applications, and very much taller seedlings than did the August applications.

Rate of application had no significant effect on seedling height at two of the four experiments during the dry summer of 1955, but in the more average year of 1956 both double and triple the normal rate of application caused appreciable height differences at Benmore. Triple rates produced a significant height increase at Bush, when compared with the two lower rates of application.

Seedling yields were unaffected by either the date or rate of 'Nitrochalk' applications, except in 1955 at Wauchope, where late sowing, coupled with the drought and cutworms, caused somewhat erratic yields; but the trend of the data indicated that lighter than normal dosage rates of 'Nitrochalk' are increasingly harmful.

There were no interactions between treatments which had any effect on seedling heights or yields.

(C) Douglas fir

The month in which 'Nitrochalk' was applied to the Douglas fir seedbeds had no appreciable effects on seedling heights at Fleet in 1955; but at Fleet in 1956, and at Benmore in both 1955 and 1956, the July and the August applications produced taller seedlings than did the June treatment. In two experiments the August application produced the tallest seedlings of all three treatments.

The rate of application of 'Nitrochalk' had no effect on seedling heights in three of the experiments, but at Fleet in 1956 the rates of 25 oz. and 37½ oz. N. per hundred square yards both produced taller seedlings than did the lowest rate (12.5 oz. N./100 sq. yds.).

No treatment had any appreciable effect on seedling yields and there were no important or significant interactions.

Conclusions

These experiments have shown that July or August is the most suitable time to apply 'Nitrochalk' as a top-dressing on Scots pine and Douglas fir rising one-year seedlings. With Japanese larch the results were not clearly defined and more experimental evidence is needed to decide this matter.

Applications of 'Nitrochalk' at rates equivalent to between twelve and twenty-five ounces of nitrogen per hundred square yards are perfectly adequate for all three species under test, and any gain obtained from higher rates of application is not commensurate with either the extra nitrogen applied or with the extra cost of the fertilizer. An exception may arise with Scots pine where an extra tenth of an inch on the mean height of seedlings which for example are one-and-one-half inches tall will increase the percentage of 'usable' plants by approximately ten per cent (Jeffers, 1955). These experiments broadly confirmed the data on rates of nitrogen application to Japanese larch and Douglas fir reported earlier in this paper.

In general, the data on seedling yields confirm that when 'Nitrochalk' is applied to conifer seedbeds at the rates specified it has no harmful effects on seedling yields.

During early autumn a close watch was kept for differential frost damage to the experimental plots. Damaging frosts were reported in early October 1955 at two nurseries, namely, Fleet where Douglas fir was sown, and Benmore where Japanese larch was the indicator species. In both nurseries all plots of seedlings were equally frosted in appearance, suggesting that nitrogen applications up to rates equivalent to 37½ ounces per hundred square yards are not associated with early frost damage. There was no record of the frost temperature which caused the damage, and therefore it is impossible to say whether a less severe frost would have been more selective.

The 1956 Experiments to Compare 0.880 Ammonia Solution with 'Nitrochalk' as a Nitrogen Manure for Seedbeds

The Experiment

The objects of the experiment were "To compare the effects on the yield and height growth of Sitka spruce seedlings, of 'Nitrochalk' applied at the standard rate for seedbeds, with 0.880 ammonia solution injected into the seedbed at three different concentrations, and both fertilizers applied either before seed sowing, or else in July". 0.880 ammonia is a solution of ammonia gas, in water, having a specific gravity of 0.880; such a solution contains approximately thirty-five per cent of ammonia by weight.

The experimental design was a 2(times of application)×4(rates and types of fertilizer) factorial, in four randomised blocks.

Seedbeds which had been partially sterilized with formalin, and fertilized with potash and phosphate manures, as described for the 1952-54 experiments, were used for these experiments,

Seed was drill sown at the rate of one thousand estimated viable seed per square yard in drills one-quarter inch deep and three-eighths of an inch wide, spaced four inches apart and each three feet long. This method of sowing was necessary so that the ammonia injections could be carried out in July without injuring the seedlings. After sowing, the seed was covered with grit.

The experiment was repeated at Inchnacardoch, Newton, Benmore, Tulliallan, Fleet and Bush nurseries.

Experimental Treatments

The two times of application were (a) on the date of seed sowing, and (b) in July. 'Nitrochalk' applications on the date of sowing were cultivated into the top three inches of soil, whereas the July applications were as two equal top dressings, one in the first and one in the third weeks of the month. Ammonia injections were made at a depth of four inches in eight equidistant holes per 3½-foot-square plot, either on the day before sowing or wholly in mid-July. Immediately after injection the holes were filled with soil, which was then tamped firm by hand.

The standard rates of ten pounds 'Nitrochalk' per hundred square yards (25 oz. N. per 100 sq. yds.) was used. 0.880 ammonia was applied at three rates, namely 2.8, 5.6 or 8.4 litres per hundred square yards (25, 50 or 75 oz. N. per 100 sq. yds.).

Effect of the Treatments on Height Growth of Seedlings

Seedling growth was particularly poor at Inchnacardoch, Benmore, Tulliallan and Fleet nurseries, and there were no significant differences between any of the ammonia treatments and 'Nitrochalk' at any of these nurseries (see Table 42). At Newton and Bush, where seedling growth was better, the standard' Nitrochalk' treatment produced the tallest seedlings. At Newton the difference in height growth between 'Nitrochalk' and the equivalent rate of ammonia (25 oz. N./100 sq. yds.), and double this rate of ammonia, was highly significant. At Bush the ammonia treatment which supplied triple the amount of nitrogen contained in the standard 'Nitrochalk' treatment, produced significantly smaller seedlings than the standard 'Nitrochalk' treatment.

Date of application had no significant effect on seedling heights at any nursery.

Effect of the Treatments on the Yield of Seedlings

Seedling yields were low at all centres except Bush, and were particularly so at Benmore. With the exception of Fleet there were no significant differences in the yield of seedlings between the standard 'Nitrochalk' treatment and the three ammonia treatments. At Fleet the two higher rates of ammonia caused a reduction in seedling numbers, when compared with 'Nitrochalk'.

At Newton the pre-sowing nitrogen application caused a definite reduction in the yields of seedlings, in comparison with July applications. At the remaining five nurseries the pre-sowing applications did not differ significantly from the July applications.

Interactions

There were no significant interactions between the date of application, and rate of application, of ammonia and 'Nitrochalk' treatments, for either mean heights or yields.

Conclusions

'Nitrochalk' at standard rates is equally as effective as ammonia when applied at rates to give equivalent amounts of nitrogen. Doubling or tripling the ammonia rates does not result in a corresponding increase in seedling heights.

Nitrogen applications, principally in the form of 0.880 ammonia solution, can be applied either on the day of sowing, or else in July, with almost equal effect.

The method of injecting ammonia into seedbeds is quite safe, feasible and effective, and is generally not harmful to the developing seedlings. In comparison with 'Nitrochalk', 0.880 ammonia does not improve or depress the yield of seedlings.

The 1956 Experiments to Compare Urea and Nitrochalk as Nitrogen Manures for Seedbeds

The Experiment

In this experiment the objects were "To compare the effects on yield and height growth of seedlings of 'Nitrochalk' and urea, when applied at two concentrations, either before sowing or as summer top dressings".

The experimental design was a 2(rates of Nitrogen) × 2(Materials) × 2(dates of application) factorial, in four randomised blocks.

The experiment was repeated at Inchnacardoch, Newton, Benmore, Tulliallan, Fleet, Bush and Wykeham nurseries.

Experimental Treatments

'Nitrochalk' and commercial urea (46.5% N.) were the two main treatments, and these were applied at rates calculated to provide either 25 or 50 oz. N. per hundred square yards, i.e. 'Nitrochalk' at approximately ten or twenty pounds per hundred square yards, or urea at 3½ or 7 pounds per hundred square yards. The third pair of treatments covered two times of application, viz. applications seven days before sowing and cultivated into the top three to four inches of soil, and applications as two equal top dressings, one in mid-July and one in the first week of August.

Effect of the Treatments on the Height Growth of Seedlings

There were no significant differences in height growth between either 'Nitrochalk' or urea, or between the two rates of application. At four nurseries, summer applications of nitrogen produced taller seedlings than did similar applications made before sowing. The reverse was true at Inchnacardoch, while at the two remaining nurseries the differences in height growth between the two treatments were not significant. Full data are given in Table 43, p. 160.

Effect of the Treatments on the Yield of Seedlings

Urea caused a reduction in seedling numbers at six out of the seven nurseries, and the difference was significant at two nurseries and highly significant in a third.

Rate of application had a slight effect on the yield of seedlings, and at all of the nurseries the higher rates of 50 oz. N. per hundred square yards produced fewer seedlings than did the lower rate of 25 oz. N. per hundred square yards. However, the difference was significant at only one nursery.

Date of application had neither beneficial nor harmful effects on seedling yields, except at Newton where for some unaccountable reason pre-sowing applications caused a highly significant reduction in yields when compared with summer applications.

Interactions

There were only two significant interactions between treatments, and both were connected with date of application and type of fertilizer. The first of these was at Inchnacardoch, where top dressings of urea produced seedlings 0.43 inches tall, whereas pre-sowing applications produced seedlings 0.66 inches tall. The date of application made no difference to seedling heights in the case of 'Nitrochalk'. At Bush the date of applying urea had little effect on seedling heights, but pre-sowing applications of urea caused a considerable and significant reduction in seedling numbers, as compared to top dressings in July. Date of application made no difference to the seedling yields in the case of 'Nitrochalk'. These facts were not confirmed at other nurseries, where roughly half showed a slight increase in yields or heights by pre-sowing applications, when compared with summer applications, while the remaining half showed decreases.

Conclusions

Both urea and 'Nitrochalk' have similar effects on the height growth of Sitka spruce seedlings when applied at rates calculated to provide similar amounts of nitrogen. Nothing is gained in the way of additional height growth by doubling the present standard rate of 25 oz. N. per 100 square yards. Top dressings of both fertilizers are generally more effective than pre-sowing dressings, and they produce slightly taller seedlings. Urea has a depressing effect on seedling yields, as compared with 'Nitrochalk'; while higher rates of nitrogen tend to further reduce the yield of seedlings. The date of applying nitrogen has generally no effect on seedling yields.

It is clear therefore that urea is not superior to 'Nitrochalk' as a nitrogen manure for Sitka spruce seedbeds.

General Discussion and Conclusions

This series of four groups of experiments has provided supplementary evidence to the report by Faulkner (1955) on the suitability of different forms of nitrogen manures for conifer seedbeds in Scotland. In addition it has partially covered the field of *when* and *how* to apply quick-acting nitrogenous fertilizers to seedbeds.

At the start of this series of experiments, the view was very widely held amongst foresters that excessive (i.e. more than 0.25 oz. N. per hundred square yards) or late (i.e. after July) applications of nitrogen fertilizers would result in overgrown seedlings which would fail to "harden off" and so be highly susceptible to early autumn frosts and possibly *Botrytis* infection. Up and until 1958 this has never been proved either by these experiments, or by demonstrations in both England and Scotland in which plots of Sitka spruce, Japanese larch or Douglas fir had been given double and triple the normal dosages of nitrogen. Schaedler (1958), working in British Columbia, has, however, reported an association of frost damage with time of application of nitrogen to one-year Sitka spruce seedlings. All the experiments reported on have failed to induce more frost damage on the heavily nitrogen-manured plots, although excessive nitrogen has been found to delay the date of terminal bud formation (Faulkner and Aldhous 1959). Furthermore, it has been shown from these experiments that applications of more than 0.25 oz. N. per hundred square yards do not necessarily result in a commensurate increase in seedling heights. In other words the present rates of nitrogen application are sufficient to ensure that nitrogen is not limiting to seedling growth.

The form in which nitrogen is applied to seedbeds has often been considered to be of great importance. Ammonium nitrogen as supplied by ammonium sulphate has on occasions produced slightly larger seedlings than has nitrate nitrogen from nitrate fertilizers; but in such cases there has usually been a suspicion that the fertilizer was supplying nitrogen and also acting as an acidification agent. Leyton (1955) produced evidence from seedlings grown in solutions of different pH values, and with nitrogen given in ammonium or nitrate form, to suggest that the root/shoot ratios of plants grown in the nitrate 'solutions' were higher than those grown in ammonium solutions. Overall, however, the total dry weights of the plants were approximately the same, irrespective of the form of nitrogen.

From the experiments which have been described here, 'Nitrochalk' (a mixture of ammonium and nitrate forms of nitrogen) was generally shown to be equally as effective as either ammonia or urea, as far as shoot growth was concerned and in nurseries where the soil pH values were within the range 4.5-6.6. This suggests therefore that the form of the nitrogen, i.e. as ammonium from urea and ammonia, or as ammonium and nitrate from 'Nitrochalk', is generally not very important for seedling growth in so far as this can be measured by shoot length.

Urea, however, caused appreciable reductions in seedling yields, and for this reason is regarded as an unsuitable nitrogen manure for seedbeds. 0.880 ammonia solution was used in the experiments, in preference to anhydrous ammonia, because it was more readily available and much easier to apply by injection. It had no harmful effect on seedling yields, and rate-for-rate it produced similar results to 'Nitrochalk'. Because it has no advantage over 'Nitrochalk' as a seedbed manure, and because it is both unpleasant and dangerous to handle, there is no point in using it further. It was perhaps unfortunate that the ammonia experiment was sited on formalin-sterilized soils, since drastic reductions in plant parasitic nematodes and fungi have been reported when ammonia was applied to soils at rates above 365 p.p.m. of soil (Eno *et al*, 1955). However, judging purely by the height growth of seedlings in the experiments described, it appears that sterilization effects from both formalin and ammonia were not substantial, since the seedling mean heights of the whole set of experiments are some of the lowest on record. Eno's work was carried out in Florida, where much higher soil temperatures are encountered than in Scotland, which would in all probability enhance the partial soil sterilization effects.

With regard to the timing of 'Nitrochalk' applications to seedbeds. In most cases there was little difference between applications given entirely *as top dressings*, and similar amounts made up of one-third applied *before* sowing with two separate thirds *during the summer*. The simpler of the two procedures is therefore recommended. The July and August applications generally produced slightly taller seedlings than did the June applications. This is thought to be due to the fact that in July and August the seedlings are slightly larger, and are therefore able to utilize more of the nitrogen through their larger root systems. Furthermore it was frequently reported that whereas seedlings which were given nitrogen in August or July had a healthy green appearance in autumn, seedlings which received nitrogen in June were yellowish-green in colour, which suggests that soil nitrogen was inadequate later in the season. In view of this, and coupled with the fact that there is little or no danger of inducing frost susceptibility through late applications of nitrogen, there are good grounds for applying nitrogen to seedbeds in both July and August.

Summing up, the experiments have indicated that 'Nitrochalk' is equal to, and in some aspects superior to, ammonia and urea when used as a nitrogen manure for conifer seedbeds. A rate of application within the range of five to ten pounds per hundred square yards is perfectly adequate for Scots pine, Japanese larch, Douglas fir and Sitka spruce, and this should be applied in two equal top dressings with one in mid-July and one in mid-August. There was no evidence to support the belief that nitrogen applications of more than 25 oz. N. per hundred square yards, applied in August, induce early frost susceptibility to the range of conifers grown.

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Table 36

First-Year Seedling Heights, in Inches, in the 1952, 1953 *and* 1954 *Experiments on Method and Time of Applying 'Nitrochalk' to Seedbeds*

Species: Sitka spruce

Treatment	1952							1953					1954				
	Inch'ch	Lit'bn. Hld.	Newton	Ben-more	Tull'n.	Fleet	Wyke-ham	Lit'bn. Hld.	Newton	Ben-more	Tull'n.	Wyke-ham	Inch'ch	Newton	Ben-more	Tull'n.	Wyke-ham
Method of Application																	
One third applied before sowing; two separate thirds as top dressing in June, July and August	1.21	1.06	1.27	1.53	0.90	2.50	0.83	2.10	1.64	2.13	1.20	1.87	1.10	1.71	1.91	1.01	0.90
Applied wholly as two top dressings in June. July or August	1.01	1.17	1.23	1.52	0.88	2.27	0.84	2.08	1.72	2.40	1.35	1.82	1.05	1.77	2.04	1.01	0.96
SE±	0.03	0.04	0.02	0.04	0.02	0.04	0.03	0.03	0.04	0.09	0.04	0.02	0.03	0.04	0.03	0.02	0.02
Critical Differences 5% 1%	0.10 0.13	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	0.10 0.14	Not Sigt.	Not Sigt.	Not Sigt.	0.26 —	0.11 —	Not Sigt.	Not Sigt.	Not Sigt.	0.09 —	Not Sigt.	Not Sigt.
Time of Application																	
Half dressing in first and last weeks June	1.18	0.98	1.16	1.47	0.82	2.24	0.78	2.04	1.40	2.06	1.08	1.73	0.89	1.70	1.69	0.90	0.85
do. July	1.00	1.12	1.34	1.51	0.93	2.39	0.84	2.01	1.76	2.43	1.35	1.76	1.06	1.78	1.93	1.06	0.90
do. August	1.18	1.21	1.28	1.52	0.90	2.47	0.78	2.14	1.69	2.22	1.39	1.96	1.16	1.60	2.21	1.05	0.98
Half dressing in Mid-June and Mid-July	1.09	1.00	1.22	1.48	0.84	2.29	0.84	2.13	1.68	2.16	1.31	1.79	1.03	1.82	1.82	0.94	0.78
do. Mid-June and mid-August	1.16	1.18	1.27	1.59	0.85	2.52	0.91	2.05	1.77	2.31	1.22	1.95	1.11	1.79	2.02	1.06	1.06
do. Mid-July and mid-August	1.06	1.19	1.20	1.57	0.98	2.42	0.93	2.18	1.80	2.41	1.29	1.91	1.25	1.76	2.17	1.07	1.00
SE±	0.06	0.07	0.04	0.06	0.04	0.06	0.03	0.06	0.08	0.18	0.07	0.05	0.06	0.08	0.06	0.03	0.04
Critical Differences 5% 1%	Not Sigt.	Not Sigt.	0.11 0.15	Not Sigt.	Not Sigt.	0.18 —	Not Sigt.	Not Sigt.	0.22 0.30	Not Sigt.	0.19 —	0.14 0.18	0.16 0.21	Not Sigt.	0.18 0.24	0.09 —	0.11 0.15

Table 37

First-Year Seedling Numbers per Square Yard in the 1952, 1953 and 1954 Experiments on Method and Time of Applying 'Nitrochalk' to Seedbeds

Species: Sitka spruce

Treatment	1952							1953					1954				
	Inch'ch	Lit'bn. Hld.	Newton	Ben-more	Tull'n.	Fleet	Wyke-ham	Lit'bn Hld.	Newton	Ben-more	Tull'n.	Wyke-ham	Inch'ch	Newton	Ben-more	Tull'n.	Wyke-ham
Method of Application																	
One-third applied before sowing; two separate thirds as top dressings in June, July or August	732	802	819	624	677	855	479	1110	1340	1200	1030	1592	1400	975	1251	1359	1475
Applied wholly as two top dressings in June, July or August	792	760	824	634	623	769	488	930	1280	1220	1080	1507	1406	978	1170	1347	1565
SE±	25	39	24	18	21	18	16	46	45	19	21	23	29	42	21	32	32
Critical Differences 5%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	52	Not Sigt.	131	Not Sigt.	Not Sigt.	Not Sigt.	66	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.
Critical Differences 1%						71		176				—					
Time of Application																	
Half dressing in first and last weeks June	779	626	801	621	629	826	398	1860	1230	1200	1160	1517	1375	879	1215	1355	1414
do. July	685	787	806	674	659	812	523	930	1350	1250	970	1530	1408	968	1170	1372	1535
do. August	715	895	810	631	686	805	506	1250	1200	1190	1100	1489	1424	1024	1130	1338	1550
Half dressing in Mid-June and Mid-July	877	719	770	592	645	807	491	860	1380	1240	1090	1604	1354	1014	1278	1433	1474
do. Mid-June and Mid-August	811	866	875	628	623	793	464	1010	1430	1220	1040	1558	1400	977	1188	1372	1587
do. Mid-July and Mid-August	705	793	871	629	656	829	520	1140	1270	1150	970	1600	1457	1009	1170	1249	1559
SE±	44	68	42	32	35	31	28	78	75	35	46	41	50	74	36	54	55
Critical Differences 5%	129	196	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	80	225	Not Sigt.	Not Sigt.	133	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.
Critical Differences 1%	—	265					—	303			—						

Table 38

First-Year Seedling Mean Heights in Inches in the 1955-7 Experiments on Rates of Application of Nitrogen Fertilizers

Treatments	1955				1956										1957			
	Sitka spruce				Sitka spruce						Japanese larch		Douglar fir		Western hemlock			
	Inch. HLN	New-ton	Bush	Wyke-ham	Inch. HLN	New-ton	Ben-more	Tull'n.	Bush	Wyke-ham	Inch.	Fleet	Ben-more	Wyke-ham	Inch. HLN	New-ton	Ben-more	Fleet
0.25 oz. N. per sq. yd.	1.73	1.66	2.57	1.68	1.17	1.67	1.80	1.19	1.50	0.72	1.21	2.24	2.13	1.80	0.54	0.38	0.76	1.15
0.50 oz. N. per sq. yd.	1.74	1.56	2.56	1.70	1.16	1.70	1.67	1.23	1.64	0.74	1.70	2.49	2.42	1.99	0.58	0.45	0.83	1.13
SE±	0.03	0.04	0.04	0.02	0.02	0.06	0.03	0.04	0.04	0.01	0.02	0.08	0.04	0.03	0.04	0.02	0.02	0.04
Critical Differences 5%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	0.09	Not Sigt.	Not Sigt.	Not Sigt.	0.07	0.25	0.09	0.08	Not Sigt.	0.04	0.07	Not Sigt.
Critical Differences 1%							—				0.10	—	0.13	0.12		0.06	—	

Table 39

Seedling Numbers per Square Yard in the 1955-7 Experiments on Rates of Application of Nitrogen Fertilizers

Treatments	1955				1956										1957			
	Sitka spruce				Sitka spruce						Japanese larch		Douglas fir		Western hemlock			
	Inch. HLN	New-ton	Bush	Wyke-ham	Inch. HLN	New-ton	Ben-more	Tull'n.	Bush	Wyke-ham	Inch.	Fleet	Ben-more	Wyke-ham	Inch. HLN	New-ton	Ben-more	Fleet
0.25 oz. N. per sq. yd.	525	846	796	891	390	464	471	628	473	573	594	748	846	775	289	493	554	652
0.50 oz. N. per sq. yd.	495	815	866	911	399	562	490	646	529	575	633	767	830	758	130	331	576	604
SE±	7	18	23	19	16	20	7	17	15	19	18	15	11	18	29	13	38	30
Critical Differences 5%	22	Not Sigt.	70	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	89	40	Not Sigt.	Not Sigt.
Critical Differences 1%	—		—												119	55		

Table 40

First-Year Seedling Mean Heights, in Inches, in the 1955 *and* 1956 *Experiments on Dates and Rates of Applying 'Nitrochalk'*

Species: Scots pine, Japanese larch and Douglas fir

Treatment	Scots pine					Japanese larch				Douglas fir			
	1955			1956		1955		1956		1955		1956	
	Inch'ch.	Tull'n.	Wykeham	Tull'n.	Wykeham	Newton	Wauchope	Benmore	Bush	Benmore	Fleet	Benmore	Fleet
Dates of Application													
Early and mid-June	2.87	1.42	2.05	1.20	0.91	4.65	1.10	2.41	3.35	4.23	3.80	3.77	3.87
Early and mid-July	2.86	1.50	1.94	1.46	0.93	4.36	1.28	2.62	3.72	4.69	4.05	4.34	4.17
Early and mid-August	2.86	1.57	1.89	1.49	1.09	4.22	1.24	2.91	2.99	4.81	3.89	4.22	4.97
SE±	—	0.07	0.03	0.04	0.04	0.08	0.06	0.07	0.10	0.08	0.07	0.08	0.08
Critical Differences 5%....	Not Anal.	Not Sigt.	0.09	0.13	0.13	0.23	0.16	0.21	0.28	0.23	0.24	Not Sigt.	0.24
Critical Differences 1%....			0.13	—	—	0.31	—	0.28	0.38	0.31	0.33		0.33
Rates of Application													
12.5 oz. N. per 100 sq. yds.	2.86	1.60	1.97	1.30	0.95	4.38	1.29	2.42	3.12	4.56	3.93	4.06	4.04
25.0 oz. N. per 100 sq. yds.	2.86	1.32	1.89	1.42	0.97	4.44	1.20	2.87	3.37	4.57	3.84	4.09	4.37
37.5 oz. N. per 100 sq. yds.	2.86	1.56	2.02	1.43	1.01	4.40	1.13	2.65	3.55	4.59	3.97	4.18	4.37
SE±	—	0.07	0.03	0.04	0.04	0.08	0.06	0.07	0.10	0.08	0.07	0.08	0.08
Critical Differences 5%....	Not Anal.	0.21	0.09	Not Sigt.	0.13	Not Sigt.	Not Sigt.	0.21	0.28	Not Sigt.	Not Sigt.	Not Sigt.	0.24
Critical Differences 1%....		—	—		—			0.28	—				—

Table 41

Total Number of Plants per Square Yard

Seedling Numbers in the 1955 *and* 1956 *Experiments on Dates and Rates of Applying 'Nitrochalk'*

Species: Scots pine, Japanese larch and Douglas fir

Treatment	Scots pine					Japanese larch				Douglas fir			
	1955			1956		1955		1956		1955		1956	
	Inch'ch.	Tull'n.	Wykeham	Tull'n.	Wykeham	Newton	Wauchope	Benmore	Bush	Benmore	Fleet	Benmore	Fleet
Dates of Application													
Early and mid-June	360	496	459	760	499	738	406	634	868	538	644	608	705
Early and mid-July	360	535	426	746	554	778	573	708	880	541	646	605	735
Early and mid-August	369	508	458	758	561	764	556	682	832	525	654	678	707
SE±	—	21	19	30	16	22	30	22	23	22	19	45	16
Critical Differences 5%.... / 1%....	Not Anal.	Not Sigt.	Not Sigt.	Not Sigt.	46 / —	Not Sigt.	89 / 120	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.
Rates of Application													
12.5 oz. N. per 100 sq. yds.	360	526	459	733	536	758	572	670	867	521	667	641	747
25.0 oz. N. per 100 sq. yds.	360	495	428	779	544	773	512	712	860	535	643	626	709
37.5 oz. N. per 100 sq. yds.	360	518	459	752	533	748	451	642	854	548	635	626	691
SE±	—	21	19	30	16	22	30	22	23	22	19	45	16
Critical Differences 5%.... / 1%....	Not Anal.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	89 / —	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.

Table 42

Seedling Mean Heights and Total Numbers in the 1956 Experiments on the Use of Ammonia as a Nitrogen Fertilizer

Species: Sitka spruce

Treatment	Mean Heights in Inches						Total Numbers per Square Yard					
	Inch'ch.	Newton	Benmore	Tull'n.	Fleet	Bush	Inch'ch.	Newton	Benmore	Tull'n.	Fleet	Bush
25 oz. N. per 100 sq. yds. as 'Nitrochalk'	0.36	1.67	0.98	0.62	1.18	1.92	375	314	260	414	489	651
25 oz. N. do. and .880 Ammonia....	0.32	1.34	0.91	0.52	1.06	1.79	388	335	241	422	446	600
50 oz. N. do. do.	0.36	1.43	0.96	0.54	1.07	1.78	351	320	243	446	421	608
75 oz. N. do. do.	0.36	1.57	0.84	0.59	1.01	1.65	317	308	220	444	428	608
SE±	0.02	0.06	0.03	0.03	0.07	0.06	32	10	14	20	17	29
Critical Differences 5% 1%	Not Sigt.	0.16 0.22	Not Sigt.	Not Sigt.	Not Sigt.	0.18 —	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	51 —	Not Sigt.
Nitrogen applied on date of sowing	0.37	1.47	0.90	0.55	1.04	1.73	332	305	253	446	440	639
Nitrogen applied in July	0.33	1.54	0.94	0.58	1.12	1.84	374	333	230	416	452	594
SE±	0.01	0.03	0.02	0.02	0.04	0.04	23	8	10	14	12	21
Critical Differences 5% 1%	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	25 —	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.

Table 43

Seedling Mean Heights and Total Numbers in the 1956 Experiments on the use of Urea as a Nitrogen Fertilizer

Species: Sitka spruce

Treatment	Mean Heights in Inches							Total Numbers per Square Yard						
	Inch'ch.	Newton	Benmore	Tull'n.	Fleet	Bush	Wykeham	Inch'ch.	Newton	Benmore	Tull'n.	Fleet	Bush	Wykeham
25 oz. N. per 100 sq. yds.	0.55	1.41	1.70	0.92	1.60	1.54	0.69	508	510	303	540	733	742	467
50 oz. N. per 100 sq. yds.	0.55	1.45	1.70	0.91	1.60	1.62	0.71	477	472	286	489	673	698	419
SE ±	0.02	0.04	0.05	0.03	0.06	0.06	0.02	16	20	7	27	17	16	19
Critical Differences } 5%.... .... 1%....	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	50 —	Not Sigt.	Not Sigt.
'Nitrochalk'	0.56	1.40	1.68	0.91	1.62	1.58	0.69	517	470	314	548	723	733	428
Urea	0.54	1.46	1.72	0.93	1.57	1.58	0.71	468	513	275	481	683	707	459
SE ±	0.02	0.04	0.05	0.03	0.06	0.06	0.02	16	20	7	22	17	16	19
Critical Differences } 5%.... .... 1%....	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	48 —	Not Sigt.	21 29	62 —	Not Sigt.	Not Sigt.	Not Sigt.
Applied 7 days before sowing	0.62	1.31	1.73	0.82	1.51	1.51	0.64	484	426	302	520	706	707	434
2 top dressings in July	0.48	1.55	1.67	1.02	1.69	1.64	0.76	501	558	288	508	700	733	453
SE ±	0.02	0.04	0.05	0.03	0.06	0.06	0.02	16	20	7	22	17	16	19
Critical Differences } 5%.... .... 1%....	0.07 0.10	0.11 0.16	Not Sigt.	0.08 0.10	0.16 —	Not Sigt.	0.05 0.07	Not Sigt.	58 79	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.	Not Sigt.

EXPERIMENTS ON THE HANDLING OF POPLAR PLANTING STOCK

By J. JOBLING

The failure of newly-planted poplar can often be attributed to one or a combination of several known and observable factors. Although these are many and varied and may, occasionally, be detected only with difficulty they are, under normal circumstances, readily discernible; the cause of death or unsatisfactory growth can usually be discovered by inspection of the plants and site. The most frequently-encountered factors limiting establishment of poplar are drought, weed competition, excess soil moisture, infection by stem fungi, damage by vermin, severe exposure, weak planting stock and poor planting techniques. These, either alone or in combination with other known causes of death or slow growth, account for probably over ninety per cent of all failed plantings during the establishment period.

Sometimes, however, the unsatisfactory behaviour of newly-planted trees cannot be attributed to any of the normal causes of failure. Such has been the case, for instance, in certain clonal trials where well-grown stock has failed for reasons not readily apparent, under conditions which had been considered optimal for poplar. Damage to the roots of the plants prior to planting has been put forward as the most likely cause of failure in these cases, particularly the damage due to exposure, either because of inadequate heeling-in or due to lack of protection during transport by lorry, which would result in drying out. In 1953 an experimental project was started to study this aspect of plant handling.

A difficulty was encountered in imposing on the plants treatments to which they were likely to be subjected in actual practice. For various reasons it was found to be impossible to simulate normal handling techniques on an experimental scale. It was decided therefore that in the experiments investigating the effects of root exposure on plant behaviour, certain of the treatments to be applied to the plants would be so extreme as to be unlikely to occur in normal practice.

Harling Exposure Experiment, 1953

The first of the experiments was laid down in 1953 at Harling, Thetford Chase, Norfolk. The soil at this site is a fen peat, two to three feet deep, overlying sand, with a pH range of 5.2-5.6. During the period the experiment was maintained, the water table seldom lay more than four feet below the surface. The site is flat and fully exposed. Six treatments were applied to the plants, which were one-year rooted cuttings stumped and transplanted for one year (C1+S1), of *Populus* 'eugenei', raised at Harling poplar nursery some 400 yards from the experimental site:

(1) Plants planted on day of lifting.
(2) Plants fully exposed for one day between lifting and planting.
(3) Plants fully exposed for four days between lifting and planting.
(4) Plants fully exposed for eight days between lifting and planting.
(5) Plants fully exposed for sixteen days between lifting and planting.
(6) Plants heeled-in sixteen days between lifting and planting.

To facilitate drying-out of the roots, the plants were laid individually on a lath shelter raised two feet above ground level, and the whole protected from rain by a tarpaulin sheet supported some four feet above the ground. All plants were planted on the same day; lifting in the nursery took place at the intervals prescribed above. The weather was exceptionally dry during the treatment period, only 0.03 inches of rain being recorded, this on the second day when only plants for Treatments (5) and (6) had been lifted. For the most part during the period, 18th February to 5th March, temperatures were very low and frost was recorded on ten days. The experiment contained five replications; treatments were randomised within the blocks. All trees were mulched after planting.

None of the treatments caused trees to die, but plants exposed for 16 days were considerably less healthy than the remainder, and they died back more during the first season. Trees exposed for eight days also exhibited die back. Because of die-back, plants subjected to the two most severe treatments were considerably shorter than plants of the other treatments, though it will be seen from Table 44 that the mean height of these at the time of planting was less than the mean height of plants of other treatments. The difference at the time of planting was not significant, however; but by the end of the second season trees exposed for 16 days were significantly smaller than trees exposed for shorter periods. Table 44 gives the mean height of plants of each treatment at the time of planting, and also at the end of the first two seasons.

Table 44

Harling Exposure Experiment, 1953

Mean height in inches

Treatment	March 1953		October 1953		October 1954	
Plants planted immediately after lifting	69.6	±1.76	75.0	±2.56	89.5	±2.75
Plants exposed for 1 day	69.2		75.3		94.7	
Plants exposed for 4 days	70.5		75.8		91.1	
Plants exposed for 8 days	67.4		70.9		85.3	
Plants exposed for 16 days	65.4		60.4		76.8	
Plants heeled-in for 16 days	72.1		79.1		95.1	
Differences for significance: 5%	5.2		7.6		8.1	
1%	7.1		10.3		11.1	

First Alice Holt Exposure Experiment, 1954

While the experiment at Harling demonstrated that plants which had been exposed for 16 days did not increase in height at the same rate as plants subjected to less severe treatments, and were also less healthy, no information was obtained on the effects of root exposure on survival. In 1954 a second experiment was laid down using the same treatments, but with one-year rooted cuttings (C1+0) of *Populus* 'robusta'. It was hoped that younger plants would be less tolerant of exposure than those used at Harling. This experiment was sited at Alice Holt, in an allotment then in the process of conversion to a stool bed nursery, where the soil is a heavy, stony clay. The nursery is sheltered to the north-west but is otherwise fully exposed.

The same techniques were used as before, and again the weather was cold and dry during most of the sixteen-day exposure period. Mulches were not applied after planting. As at Harling, no deaths occurred due to any treatment. During the first season all plants were healthy, and only occasional die-back occurred, which could not be related to experimental treatment. Height growth was vigorous with all trees, particularly for the first season on this type of soil, and showed no relation to period of exposure. The mean height of plants of each treatment, for beginning and end of season, are given in Table 45.

Table 45

First Alice Holt Exposure Experiment, 1954

Mean height in inches

Treatment	April 1954	October 1954
Plants planted immediately after lifting	60.5	76.5
Plants exposed for 1 day	62.4	78.2
Plants exposed for 4 days	61.7 } ±1.30	78.2 } ±2.07
Plants exposed for 8 days	61.0	77.2
Plants exposed for 16 days	63.6	82.2
Plants heeled-in for 16 days	62.5	79.1
Differences for significance: 5%	2.8	6.1
1%	5.3	8.3

Because this experiment appeared unlikely to yield useful information no further assessments were carried out in it.

Second Alice Holt Exposure Experiment, 1955

Exposure treatments were made considerably more severe in the third experiment of the series planted, at Alice Holt Forest, in 1955. This was located on heavy clay soil, derived from the Gault Clay, and showing severe gleying at fifteen to eighteen inches. The site formerly bore hazel coppice with scattered oak standards; at the time the experiment was laid down the vegetation consisted mainly of grasses and bramble with hardwood coppice occurring locally. The experiment was sheltered on three sides.

The plants, one-year rooted cuttings stumped and transplanted for one year (C1+S1) of *Populus* 'serotina erecta', were imported from Fenrow Nursery, Rendlesham Forest, Suffolk, and the following treatments applied to them on their arrival at Alice Holt:

(1) Plants exposed for 40 days.

(2) Plants heeled-in 10 days, then exposed 30 days.

(3) Plants heeled-in 20 days, then exposed 20 days.

(4) Plants heeled-in 30 days, then exposed 10 days.

(5) Plants heeled-in 35 days, then exposed 5 days.

(6) Plants heeled-in for 40 days.

The roots were exposed by the techniques used at Harling. The weather during the treatment period, from 18th January to 1st March, was very cold and on many days the temperature fell below freezing point. For long intervals the soil of the heeling-in pit was frozen hard. The experiment contained five replications; the treatments were randomised within blocks. All trees were mulched for the first three seasons.

The pattern of behaviour after planting was similar to that noted earlier. None of the trees died, though some exhibited crown die-back during the first season. The amount of die-back could not be related to treatment, however. All trees were equally healthy during the first and subsequent seasons. Height growth was variable, but no significant differences were detected between the mean heights of plants of the six treatments. Table 46 gives the mean heights of the trees of each treatment at the end of the first four seasons.

Table 46

Second Alice Holt Exposure Experiment, 1955

Mean height in feet

Treatment	October 1955	October 1956	October 1957	October 1958
Plants exposed 40 days	4.47	5.53	7.06	8.67
Plants heeled-in 10 days, exposed 30 days	4.35	5.34	7.015	8.915
Plants heeled-in 20 days, exposed 20 days	4.28	5.03	6.325	7.94
Plants heeled-in 30 days, exposed 10 days	4.65	5.63	6.985	8.655
Plants heeled-in 35 days, exposed 5 days	4.51	5.40	7.195	8.915
Plants heeled-in 40 days	4.49	5.44	6.96	8.63
Standard Error	±0.08	±0.20	±0.26	±0.38

From the results of the three experiments described above, it may be assumed that, since exposure of the roots of poplar for relatively long periods does not affect survival, lack of protection during transport by lorry is unlikely to be a direct cause of failure. Similarly it is doubtful if inadequate heeling-in alone, except for periods of over forty days, affects survival. In cases where one or more of the factors listed above are limiting, however, root exposure may contribute towards failure. The effects of root exposure for periods in excess of forty days have not been tested, as it is highly improbable that nursery plants allocated for field planting would be so mis-handled. While it is apparent from the work that survival is not affected by root exposure, even after prolonged periods, the data from the experiment at Harling indicate that growth during the first and second season may be affected, and the overall results should in no way encourage the mis-handling of poplar planting stock.

Heeling-in Experiment, 1955

The possibility that heeling-in techniques might be related to the failure of newly-planted poplar was tested at Alice Holt in 1955. The plants, imported from Fenrow Nursery, Rendlesham Forest, were one-year rooted cuttings stumped and transplanted for one year (C1+S1) of *Populus* 'eugenei'. The treatments applied to the plants on their arrival at Alice Holt were as follows:

(1) Plants heeled-in as normal for 40 days.

(2) Plants heeled-in in water-saturated soil for 40 days.

(3) Plants with roots totally immersed in water for 40 days.

(4) Plants heeled-in as normal 20 days, transferred to water-saturated soil for 20 days.

(5) Plants heeled-in as normal 20 days, following by immersion of roots in water for 20 days.

(6) Plants heeled-in in water-saturated soil 20 days, followed by immersion of roots in water for 20 days.

In treatments (2), (4) and (6) the soil of the heeling-in pit was retained in a water-saturated state by periodic hosing. In Treatments (3), (5) and (6) plants were stood in an upright position in a cistern with water completely covering the roots to root collar level. The treatments were applied during a prolonged spell of cold weather, 10th January to 21st February, and for much of the time the ground was hard, and the water in the cistern was either partially frozen or completely frozen. It is very likely, therefore, that the value of the treatments was somewhat reduced by the weather, in spite of the fact that efforts were taken to retain their individuality.

The experiment, containing five replications, with treatments randomised within blocks, was sited adjacent to the "exposure" experiment described above. Survival was one hundred per cent for all treatments, health was uniform, and no significant differences in height were detected, except at the end of the second growing season when the mean height of plants of Treatment (5) were smaller than all others except of Treatments (3) and (4), and plants of Treatment (4) were smaller than those of Treatments (1) and (2). However, examination of the data, particularly those of the previous year and the two subsequent years, suggests that the height differences were not directly due to treatment effects. The mean heights of the plants at the end of each of the first four seasons are given in Table 47.

Table 47

Alice Holt Heeling-in Experiment, 1955

Mean height in feet

Treatment	October 1955	October 1956	October 1957	October 1958
1. Normal heeling-in 40 days	5.165	6.14	7.44	8.025
2. Heeling-in in water-saturated soil 40days	5.055	6.065	7.25	8.560
3. Immersion of roots in water 40 days	4.740	5.860	7.25	8.720
4. Normal heeling-in in 20 days, heeling-in in water-saturated soil 20 days	4.685	5.675	7.05	8.475
5. Normal heeling-in 20 days, immersion of roots in water 20 days	4.685	5.490	6.93	8.278
6. Heeling-in in water-saturated soil 20 days, immersion of roots in water 20 days	4.900	5.915	7.14	8.305
Standard Error	±0.132	±0.134	±0.197	±0.272

Root Pruning Experiments, 1954

Two experiments started in 1954, at Garadhban Forest, Stirlingshire, and Forest of Dean, Gloucestershire, are both indirectly concerned with handling of poplars. These experiments were designed to compare the behaviour, after planting, of different age-types of stock. Two types of rooted cuttings were included in each, and to study the effects of root damage on subsequent behaviour in the field, roots were severely pruned immediately the plants were lifted in the nursery. It was hoped that by root-pruning—all roots were cut back to within two inches of the original cutting—information would be obtained relating to careless lifting in the nursery and other maltreatment before planting, including damage during transport and heeling-in. In fact, in neither experiment did the treatment have any detrimental effect on behaviour. At Garadhban Forest root-pruned plants, from the first season onwards, grew at the same rate as plants which had not been pruned, of both one-year rooted cuttings stumped and transplanted for one year (C1+S1) and one-year cuttings stumped and transplanted for two years (C1+S2) of *Populus* 'gelrica'. In the Forest of Dean two varieties were used, *P.* 'robusta' and *P. tacamahaca*×*trichocarpa* 32, and the types of plant were one-year rooted cuttings (C1+0) and one-year rooted cuttings stumped and transplanted for one year (C1+S1). In this experiment also root pruning had no detrimental effect on behaviour. The data show in fact that the plants which were root pruned maintained a similar rate of growth to plants not root pruned. At the time of planting the mean heights of root-pruned trees were slightly greater than the mean heights of trees not root pruned, and these differences have remained the same or have slightly increased during the five years the experiment has been in progress. Both age-types of plant of each variety have behaved similarly in this respect. The data given in Table 48 are for *P.* 'robusta', showing the mean heights of plants of each root-pruning treatment at the end of each of the first four seasons.

Table 48

Forest of Dean Root-Pruning Experiment, 1954

Populus 'robusta' — Mean height in feet

Treatment	October 1954	October 1955	October 1956	October 1957
C1+0—not root pruned	5.47	8.43	11.51	16.61
C1+0—root pruned	5.61	8.76	12.43	17.18
C1+S1—not root pruned	5.62	8.75	12.07	16.88
C1+S1—root pruned....	5.84	9.11	12.28	17.26
Standard Error	±0.107	±0.140	±0.272	±0.234

At the time of planting, root-pruned plants of one-year rooted cuttings (C1+0) had a mean height only 0.07 feet greater than unpruned plants, while for one-year rooted cuttings, stumped and transplanted for one year (C1+S1) the basic difference in height was 0.11 feet, root-pruned plants being the taller. The differences in mean height of root-pruned and non-pruned plants of *P. tacamahaca*×*trichocarpa* 32 have remained constant since the end of the first season. During the first season root-pruned plants of this variety grew slightly faster than plants which had not been pruned.

This work, while by no means conclusive, suggests that the consequences of accidental severance of roots during lifting, and possibly at any other time before planting, are not as serious as had hitherto been believed. While the type of damage that occurs during lifting is somewhat different from the pruning carried out in the two experiments—the former generally involves a stripping or tearing of roots—the fact that plants bearing only the stubs of roots will survive as well as, and grow at the same rate as, plants with a full root system confirms that poplar will withstand considerable root damage without any appreciable effect on subsequent behaviour. Again, however, this knowledge should not lead to deliberate or careless mis-handling of stock.

Conclusions

(1) Poplar will withstand considerable root exposure without affecting rate of survival. Exposure for periods up to 40 days is unlikely to result in failure.
(2) Health and early rate of growth may be poorer in plants that have been exposed, but the effects are temporary. Crown die-back may occur on plants exposed for periods of sixteen days or longer.
(3) Root severance at time of lifting is unlikely to affect survival or the early rate of growth.
(4) The tolerance of poplar to various forms of root damage during handling is similar for different age-types of stock and for different varieties. The results are similar when damaged plants are transferred to sites of different character.

RESURVEY OF DISTRIBUTION OF THE BARK BEETLE IPS CEMBRAE

By Dr. MYLES CROOKE and R. C. KIRKLAND

The bark beetle *Ips cembrae* Heer. was first discovered in north-east Scotland during 1955. In that year a survey was made to determine its distribution and the results published (Crooke and Bevan, *Forestry*, XXX, 1, 21-28, 1957).

In May, 1957, the Conservator, East Scotland, reported finding *I. cembrae* at Newtyle Forest, five miles south of Forres, Morayshire. This is within the known area of distribution. Breeding had apparently taken place in larch logs which had been cut to clear a new roadline, and beetles had spread from there to nearby standing 19-year-old European larch and young Japanese larch. Some of these otherwise healthy trees had been killed by the bark beetle attack.

In early September, 1958, a survey was made round the perimeter of the known distribution area with the object of determining whether or not spread had occurred. The results of this survey are presented in Table 49 and Plate 5. It will be evident from the latter that the only significant extensions of distribution have taken place to the south-east, where the record at Drummuir (16) is 6 miles from the last recorded one; and to the north, where the records at Novar (4) and Ardross (5) are respectively 19½ and 22 miles from the last recorded localities.

These new records, as were the ones made during the 1955 survey, were based upon finding either breeding systems or the typical bored larch shoots, or both.

Freshly bored shoots were located at sites 7, 8, 10, 11 and 14, and active breeding populations at sites 4, 5, 8, 12, 14, 15 and 16. These latter were restricted, with but one exception, to felled material of which the majority was "in stack" at rideside or near local saw benches. Thus, at Novar, beetles occurred in the sawmill and on stacked rideside logs; at Ardross, on rideside stacks of logs; at Burgie and Seafield (Rothes) in logs at saw benches adjacent to larch plantations; at Ballindalloch on logs in a sawmill; at Drummuir on about sixty large stems which had been cut and left at the edge of a stand; and at Scootmore on a few logs left lying in the wood by the contractors. In one case, however, at Ardross, breeding systems occurred in standing dead poles of 19 years of age, while standing living stems in the same wood showed signs of attempted colonisation. Long mother galleries, usually running vertically, had been cut in these stems, but the brood had failed to develop from them. The stems showed cracks and heavy resin bleeding at the points of attack. It seems probable, therefore, that the dead standing infested trees represent successful colonisation, and that the death of these trees can be attributed to invasion by *Ips cembrae*. Apart from the presence of beetles, no other pathological symptoms were detected on the dead trees.

This resurvey of the distribution of *I. cembrae* is incomplete, in that time prevented it being continued northwards from Ardross into areas where other larch stands occur. It is planned to cover this area when opportunity offers and also to extend the survey further up Strathspey.

Table 49

Details of Occurrences of Ips Cembrae in 1958

County	Ref. No.	(of) Locality	1" O.S. Ref. No.	Area Examined	Occurrence of Ips Cembrae
ROSS & CROMARTY	1	SLATTADALE	26/886718	Mill, and pole stage larch. Extensive	Nil.
—do.—	2	LAEL	20/192818	Mill, and early pole stage larch. Extensive	Nil.
—do.—	3	CORRIEMOILLIE LODGE	27/362636	Small Policy woods. Old E.L. in S.P. and Birch area	Nil.
—do.—	4	NOVAR	27/626678	Inchcholtair Wood and Sawmill	Breeding beetles present.
—do.—	5	ARDROSS	27/658735	E.L. Comps. 2-7	Heavy infestation of rideside poles and invasion of standing trees.
INVERNESS-SHIRE	6	FARIGAIG	37/550281	Old E.L. Thinned trees present	Nil.
NAIRNSHIRE	7	GLENFERNESS	38/960450	Old and overmature E.L.	Bored shoots and old galleries present.
MORAYSHIRE	8	BLERVIE	28/062553	Small plantation, policies and mixed E.L. and S.P.	Shoots and immature beetles in log at mill.
—do.—	9	BURGIE	28/092578	Pole stage larch plantations adjacent to Monaughty forest	Beetles breeding in logs at mill. (Thinnings.)
—do.—	10	PLUSCARDEN	28/130560	Advanced pole stage larch plantations	Few shoots present.
—do.—	11	INNES	29/291620	Sleepieshill Wood, old overmature E.L. stand	Old galleries and new shoots.
—do.—	12	RIDDOCH (Seafield)	29/237567	Mill alongside young larch plantations	Many breeding beeltes in logs at mill. (Thinnings).
—do.—	13	ELCHIES area	39/262445	Open stand of E.L. about 30 years old. Small stand on waterlogged site	Dying and dead trees. No Ips.
BANFFSHIRE	14	SCOOTMORE FOREST	39/176387	Larch plantations, middle pole stage	Shoots present. Beetles breeding in logs left by Contractors.
—do.—	15	BALLINDALLOCH	39/177360	Saw mill	Many logs infested and dead trees standing with old galleries.
—do.—	16	DRUMMUIR	39/364418	Old E.L. approaching final thinning. Windblown trees cut from stump	Heavy infestation by beetles breeding in all cut trees.
—do.—	16A	—do.—	355440	Plantations with long history of windthrow	No sign of Ips.
—do.—	17	SEAFIELD (Cullen)	29/495655	Extensive larch plantations and much produce	—do.—
ABERDEENSHIRE	18	TARRYBLAKE	29/580487	Remnants of gale damaged E.L. in all stages of ill health	—do.—
—do.—	19	BLAIRMORE	39/434393	Fairly extensive larch plantations, some windthrow	—do.—

STUDIES OF THE INDUMENTUM OF YOUNG SHOOTS OF NORWAY SPRUCE IN SOME SCOTTISH PROVENANCE EXPERIMENTS

By ROGER LINES

Introduction

Existing provenance trials with Norway spruce (*Picea abies* Karst.) both in this country (Edwards 1955) and on the Continent (Vincent and Flek 1953, Langlet 1953) have demonstrated that there exist provenances which show a wide variation in growth vigour, which implies that their physiology is in some way different. Recognition of the faster or slower growing provenances by their morphological characters is not easy, and due to differences in the site fertility within the experiments, it is very difficult to pick out those provenances which are best equipped physiologically for growing in British conditions. The possibility that the hairiness (indumentum) of the young shoot might be used to distinguish different provenances or groups of provenances was therefore thought to be worth investigation, especially since variations in the cone scales will not be evident for many years, since most trees are too young to bear cones.

Even in recent years the variation in the indumentum of Norway spruce shoots has caused a certain amount of disagreement between the description of different authors. Dallimore and Jackson (1948) use the indumentum of the young shoot as an important distinguishing character in their key to the genus. *Picea abies* is placed in the section which has "young shoots glabrous or slightly hairy". They add that "The student, however, must be prepared to find trees with hairy shoots". Bean (1950) notes that the branchlets are "usually more or less downy, sometimes glabrous". Rehder (1954) gives a choice: "glabrous or minutely pubescent". The most detailed investigation of the indumentum of Norway spruce shoots to date has been made in Sweden by Lindquist (1948) and his studies will be referred to again below.

Field Work

The opportunity to study the indumentum of the shoots of different provenances of Norway spruce came in the summer of 1957 when a forestry student (J. Horsman) commenced work in the International Norway Spruce Provenance Experiment at The Bin Forest, Aberdeenshire. He was not able to draw detailed conclusions, as the data were not analysed until some time after his survey was completed (Horsman, 1958). Further assessments were made in Newcastleton Forest, Roxburghshire, and a brief description of these areas will now be given.

The International Norway Spruce Experiment at The Bin comprises eighteen provenances from Scandinavia, Latvia, Poland, Germany, Switzerland, Italy, the Middle Danube and Eastern Europe. Details of the provenances are given in Table 52. These provenances were planted in plots of 250 plants, in a randomised block design with five replications. The site carried a previous crop of conifers, mostly Norway spruce, which were clear felled in 1934. The experiment was planted in 1942, by which time the area was covered by a dense growth of the grasses *Deschampsia caespitosa* and *Holcus* spp., and in some places the rush *Juncus effusus*. Within a few years of the initial draining there was a strong increase in the growth of heather, *Calluna*, which has caused a check to growth over a large part of the experiment. The experimental area is on a gentle slope facing south-west and is moderately sheltered. The elevation is 550-600 feet and the annual rainfall approximately 34 inches. The soil is a Brown Earth with gleyed horizons (Muir and Fraser 1940). As a result of the check caused by *Calluna* over part of the area, the data for the mean height of each provenance (shown in Table 50) do not necessarily represent its growth potential, since some provenances are wholly on the better vegetation types, while with other provenances all plots are affected to some extent by check.

At Newcastleton, eleven provenances of Norway spruce were planted in 1938 in a randomised block design with five replications. The plots were originally planted with 30 plants but, due to frost damage, the number of plants in some plots has been seriously reduced. An account of this frosting (Edwards, 1955) has shown that it was associated both with provenance and the size and type of the trees at planting. The details of origin of the provenances used in this experiment are less exact than those of The Bin experiment, and the geographical range covered is less.

The experiment is situated on a gentle slope with a southerly aspect at an elevation of 750 feet. The ground vegetation is dominated by purple moor grass, *Molinia caerulea*, and the soil is a shallow peat over a clay-loam.

A preliminary investigation at The Bin soon showed that the mean height of the tree made little difference to the shoot indumentum, although on the trees in checked areas the shoots were smaller than on vigorously growing trees. The majority of the trees sampled were still in the individual tree phase, before canopy closure had taken place, although in some cases this had occurred. (In the Newcastleton experiment the trees were older and for the most part had closed canopy.)

Newly-extended side shoots were picked from seven or eight trees on each side of the square plot, so as to obtain a total of 30 shoots embracing every aspect. They were put in a plastic bag which had been previously labelled with the plot number and the identity number of the provenance. The shoots were taken back and examined under a binocular microscope. The part of the shoot examined was the area about 1 cm. from the base of the shoot, and it was found possible to estimate fairly accurately the number of hairs appearing in the microscope field. Since it would have been too laborious to count the hairs on every individual shoot (more than 3,000 shoots were examined) it was decided to allocate a score with six classes: 0, 10, 20, 30, 40, 50, which corresponded to the approximate number of hairs visible in the microscope field of 2.8 mm. The mean score for each plot was then calculated, and the mean for the five replications of each provenance obtained. An examination of the data showed that a transformation of plot scores was required for a valid statistical analysis. The transformation used was $\sqrt{x+0.5}$. The results are shown in Table 50; the fourth column shows the mean value for the indumentum, after back transformation from the statistically adjusted data, and these values therefore may be read approximately as the mean number visible in the microscope field.

The back-transformed mean score for the indumentum has been plotted diagrammatically in Plate 2, which also shows the location of the provenances.

At Newcastleton shoots were sampled in a similar manner to that at The Bin, except that only 10 outside trees could be sampled instead of 30.

The data were transformed and analysed in the same way as those from The

Bin, and they are shown in Table 51. Details of the provenances are shown in Table 52. Where the provenance origins are reasonably exact their positions have been plotted on the map (Plate 2) and the mean score for the shoot indumentum shown diagrammatically.

Results and Discussions

It will be seen from Plate 2 and Tables 50 and 51 that shoot indumentum is clearly a character which varies greatly in Norway spruce. On the one hand there are provenances which could be regarded as almost completely lacking shoot hairs (e.g. Sarajevo and Winterthur), while in others, such as Vilppula and Follafoss, the occurrence of a glabrous shoot is the rare exception. The provenances can be grouped in the zones of Rübner's classification (1934) and when this is done the statistical analysis shows that there is a highly significant difference between the northern group of provenances, which have a heavy indumentum, and those of the Hercynian-Carpathian and Alpine-South-East Europe groups which have slight indumentum or none at all. The provenances of the Hercynian-Carpathian group have significantly more shoot hairs than those of the Alpine group, but the difference between these two groups is less striking. Most of the variation can be accounted for statistically by the variation between groups, but intra-group variation is also significant within all groups.

The provenances from Obervellach offer the only chance of comparing two lots from the same area but at different elevations. The high elevation (6,000 feet) one has a mean indumentum score half that of the low elevation (3,000 feet) provenance, but this difference is not quite significant at the 5% level. Examination of the data for all provenances for a correlation between elevation and the indumentum score does not show an obvious relationship, even for provenances in the same group or at the same latitude. The mean indumentum scores for the Rumanian provenances, Crucea and Vadul Rau, indicate a decrease in the number of hairs with increasing elevation, but if one also considers the Mt. Bihor provenance in the Newcastleton experiment it will be seen that this origin has both the highest elevation and the highest mean score for indumentum.

The pattern of the variation in shoot indumentum, which is shown in Plate 2, could be explained partly on the basis of latitude, if one accepts the hypothesis that the more northerly the provenance the greater the indumentum. But on this hypothesis it is impossible to explain the rather high values for the indumentum of the Rumanian provenances, and the relatively small difference in the mean score between the south Sweden and Latvian provenances on the one hand and the Norwegian and Finnish ones on the other.

For a deeper understanding of the causes of the present distribution of indumentum types of Norway spruce, one must consider the situation at the close of the last glacial period. According to Lindquist (1948), the spruce of Tertiary times, which had been forced to retreat during the Quaternary Ice Age to three ice-free centres (Central Russia, Rumania and the Apennine region) during the Boreal period, once more invaded Northern and Central Europe. There is reason to believe that the glacial period had eliminated spruce from Norway and Sweden (except for certain northern nunataks) so that subsequent invasion had to be via northern Finland. Only ecotypes which were capable of successful growth and seed propagation in this area (mostly within the Arctic

Circle) survived to spread their progeny down into southern Sweden. This similarity of gene history between all the Scandinavian groups of provenances offers a possible explanation for the homogeneous character of their indumentum. Stolpce in North Poland appears to be the sole exception to this homogeneity, perhaps because it is the most southerly member of the group.

The present-day Hercynian-Carpathian distribution of spruce has been traced (Pop 1929) back to a glacial refuge in Transylvania, and appears to have subsequently linked up with the Alpine group. Very little can be said about the indumentum of the pre-glacial spruce populations, and the point in history when the three major groups of provenances began to diverge in their hairiness may have pre-dated the last glacial epoch. It does seem clear that *after* the glaciers had retreated there emerged three distinct population groups (corresponding to Rübner's) which can be differentiated biometrically on the basis of their differences in shoot indumentum.

The Alpine group of provenances probably derive from a glacial refuge in the Apennine Peninsula (Keller, 1930), whence they spread out to the west and over the Alps to Switzerland and the Black Forest and the Vosges. According to Danilow (1943) the Central European spruce also extended eastwards to meet the Russian spruce populations in late sub-Atlantic times.

Mention has been made of the exhaustive Swedish work on the shoot indumentum of Norway spruce by Lindquist (1948). The greater part of this work consisted of collecting more than 60,000 shoots from all over Scandinavia and determining the relative frequency of the different indumentum classes. He also had shoots sent to him from all parts of the natural range of *Picea abies* and from the European part of the range of *Picea obovata*. Unfortunately, his data have not been treated statistically, and it is not easy to make comparison between provenances.

Apart from his numerous samples from Scandinavia he also investigated the shoot indumentum of spruce from Switzerland and on a smaller scale the indumentum on the trees in provenance experiments in both Sweden and Denmark. In certain cases they were the identical provenances which are growing at The Bin and it is of interest to compare the results (see Plate 3). This cannot be done directly since he gives no mean score for a provenance. However, by multiplying the number of trees in each of his five classes by the class number, and dividing the total by ten, one obtains roughly comparable figures. Unfortunately, he did not sample the Scandinavian provenances in the International Provenance Experiment, so typical provenances from the same locality have been substituted. The values obtained in the Scottish and Scandinavian experiments have been plotted in Plate 3, from which it will be seen that there is a high correlation between these independent estimates. (Correlation coefficient +0.98.)

The results of the Newcastleton experiment do not show any substantial divergencies from the pattern disclosed by the other experiments. As has been pointed out above, the provenances are mostly from the Alpine group and the sole provenance from Scandinavia (Östersund) is not fully replicated and has suffered very badly from earlier frost damage. After transformation by the $\sqrt{x+0.5}$ method, the results were analysed and are shown in Table 51. A column has been added to show the mean height of each provenance at the age of 16 years.

Correlation Between Seed Weight and Indumentum

A preliminary examination of the data for the weight of 1,000 seeds of each provenance appeared to show a correlation with the indumentum score. Delevoy (1949) has already pointed out that the seed weight decreased with increases in either latitude or altitude, and by plotting the transformed mean score for the shoot indumentum against the weight of 1,000 seeds for each provenance, it was seen that there was a relationship between these two factors (Plate 4). The correlation co-efficient between them was − 0.87, which is significant at the 1% level. It seems that both are affected in the same way by latitude or some other factor.

The clearest correlation is again with the geographical zone. The fact that the high and middle latitude provenances are mostly from a comparatively low elevation, while the southermost ones are from a high elevation, makes it difficult to separate the effects of latitude from those of elevation with reasonable precision.

In general it can be said that the northern group of provenances have a high indumentum value and a low seed-weight, while the Hercynian-Carpathian group have a lower indumentum value but high seed-weight, and the Alpine-S.E. European group have the lowest indumentum value coupled with a moderately high seed-weight.

Conclusions

From the rather limited number of assessments of shoot indumentum which have been carried out it is possible to draw the following tentative conclusions:

(1) Norway spruce provenances differ significantly in their shoot indumentum; the Baltic and Northern provenances being markedly hairy, while those of the Central Alps and Jugoslavia are largely glabrous.

(2) The variation can be explained on a statistical basis, as being chiefly between geographical groups of provenances, rather than between individual provenances within a group.

(3) The variation of the indumentum does not seem to be closely correlated with latitude, longitude or altitude.

(4) The present work has confirmed previous studies on the geographical distribution of this variation.

(5) In The Bin experiment a significant correlation was shown to exist between seed weight and the shoot indumentum.

(6) Samples of 150 shoots from a provenance are sufficient to give a clear indication of the geographical group from whence it came.

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Table 50

Indumentum Mean Score and Mean Heights for Different Provenances. International Experiment at The Bin Forest, Aberdeenshire

Provenance	Reference No.	Mean score for indumentum		Mean height at 10 years feet
		Transformed $\sqrt{x+0.5}$	Back Transformed	
Group I Alpine and south-east Europe				
Winterthur	13	1.74	2.5	3.4
Val de Fiemme	14	2.05	3.7	3.7
„ „ „	14a	2.34	4.9	4.1
Lankowitz	16	1.74	2.5	4.2
Obervellach (High)	17	1.63	2.1	3.4
„ (Low)	18	2.19	4.2	3.6
Sarajevo	19	1.47	1.6	3.8
Burgenland	—	2.11	4.0	4.1
Means	—	1.91	3.2	3.8
Group II Hercynian-Carpathian				
Pförten	8	2.20	4.3	4.6
Istebna	10	2.50	5.8	4.2
Crucea	20	3.49	11.6	4.6
Vadul Rau	21	2.50	5.8	4.2
Means	—	2.67	6.9	4.4
Group III Baltic and Northern				
Vilppula	2	5.37	28.3	3.5
Tyldal	3	5.13	25.8	2.5
Nes	4	5.16	26.1	3.8
Follafoss	5	5.29	27.5	3.9
Drängsered	6	5.15	26.5	4.6*
Vecmoka	7	5.18	26.3	3.9*
Stolpce	9	3.94	15.0	4.1
Means	—	5.03	25.1	3.8
Standard error		±0.21	—	—
Difference for significance: 5%		0.60	—	—
1%		0.79	—	—

* The plots of these provenances are situated on better vegetation types than the others.

Table 51

Indumentum Mean Score and Mean Heights for Different Provenances in Experiment No. 4, *Newcastleton Forest, Roxburghshire, Planted* 1938

Provenance	Identity No.	Mean score for indumentum		Mean height at 16 years feet
		Transformed $\sqrt{x+0.5}$	Back Transformed	
Group I Alpine and south-east Europe				
Black Forest	34/42	1.80	2.8	15.0
Black Forest	35/31	2.50	6.2	16.2
Black Forest	36/15	2.44	5.6	10.0
Austria	33/11	2.06	3.8	15.3
Inn Valley	34/35	2.46	5.6	13.8
Inn Valley	35/28	1.94	3.4	13.0
Isarco Valley	34/54	2.73	7.2	13.2
Isarco Valley	35/41	1.89	3.4	14.6
Central Alps	36/17	2.36	5.4	12.1
Means	—	2.13	4.8	13.7
Group II Hercynian-Carpathian				
Rübeland	36/19	2.36	5.6	10.6
Mt. Bihor	34/56	3.75	13.8	17.0
Means	—	3.05	9.7	13.8
Group III Northern				
Östersund	32/542	(3.38)*	(11.0)*	(9.1)*
Standard error		±0.23	—	±0.72
Difference for significance at 5%		0.65	—	2.05
1%		0.87	—	2.74

* Mean of only two replications and therefore excluded from the analysis.

Table 52

List of Provenances in The Bin and Newcastleton Experiments

International Reference No. or F.C. Identity No.	Origin	Elevation feet	Lat. N.	Long E.
2	Vilppula, Hame, Finland	400	62° 3′	24° 27′
3	Tyldal, Hedmark, Norway	1,800	62° 9′	10° 49′
4	Nes S. Trondelag, Norway....	660–1,300	63° 45′	9° 35′
5	Follafoss, N. Trondelag, Norway	200–300	64° 0′	11° 7′
6	Drängsered, Halland, Sweden	1,200?	57° 5′	13° 0′
7	Vecmoka, Tukums, Latvia	250	57° 0′	23° 7′
9	Stolpce, Minsk, Poland	550–600	53° 28′	26° 43′
8	Pförten, Brandenburg, Germany	230	51° 47′	14° 46′
10	Istebna, Kracow, Poland	2,000	49° 35′	18° 58′
20	Crucea, Neamt, Rumania	2,400	46° 45′	26° 20′
21	Vadul Rau, Severin, Rumania	3,500	45° 10′	22° 20′
13	Winterthur, Zurich, Switzerland	1,600	47° 31′	8° 44′
14	Val de Fiemme, Trento, Italy	3,300–4,000	46° 18′	11° 20′
14a	,, ,, ,, ,, ,, ...	,,	,,	,,
16	Lankowitz, Steiermark, Austria	1,700	47° 5′	15° 0′
17	Obervellach, Kärnten, Austria	6,000	46° 55′	13° 13′
18	,, ,, ,, ...	2,600–3,300	,,	,,
19	Sarajevo, Hercegovina, Yugoslavia....	4,000	43° 50′	18° 30′
37/26	Burgenland, Austria	600–1,600	47° 48′	16°–17°
32/542	Östersund, Jamtland, Sweden	300–1,000?	63° 10′	14° 41′
36/19	Rübeland State Forest, Harz Mts., Germany	1,500	51° 44′	10° 52′
34/56	Valea Mare and Urbanistilor forests, Mt. Bihor, Rumania	3,600–5,600	46° 19′–31′	22° 41′–23° 3′
34/42	Black Forest, Germany	—	48°–49°	8°– 9°
35/31	Freudenstadt-Horb-Nagold, Black Forest, Germany	1,470–2,300	48° 27′–32′	8° 25′–44′
36/15	,, ,, ,, ...	,,	,,	,,
33/11	Austria	650–1,650	46°–49°	10°–17°
34/35	Inn Valley, N. Tyrol, Austria	1,950–2,600	47°–47½°	10°–12°
35/28	,, ,, ,, ,, ...	,,	,,	,,
34/54	Isarco Valley, Trentino, Italy	2,300–3,900	46° 50′–47°	11° 30′–40′
35/41	,, ,, ,, ,, ,, ...	,,	,,	,,
36/17	Central Alps	—	46°–47°	7°–10°

APPENDIX I

List of Main Experimental Projects and Localities

While most of the investigations and experiments of the Research Branch are scattered throughout forests all over the country, there are certain areas where work on some projects is more or less concentrated. These are briefly given below:

NURSERY EXPERIMENTS

Benmore Forest Nursery, near Dunoon (Argyll)
Bramshill Nursery (Hampshire)
Bush Nursery, near Edinburgh
Fleet Forest Nursery, Gatehouse of Fleet (Kirkcudbrightshire)
Inchnacardoch Forest Nursery, near Fort Augustus (Inverness-shire)
Kennington Nursery, near Oxford
Newton Nursery, near Elgin (Morayshire)
Sugar Hill Nursery, Wareham Forest (Dorset)
Tulliallan Nursery (Fife) near Alloa

AFFORESTATION EXPERIMENTS ON PEAT

Achnashellach Forest (Ross-shire)
Beddgelert Forest (Caernarvonshire)
Clocaenog Forest (Denbighshire)
Inchnacardoch Forest (Inverness-shire)
Kielder Forest (Northumberland)
Strathy Forest (Sutherland)
Wauchope Forest (Roxburghshire)

AFFORESTATION EXPERIMENTS ON HEATHLAND

Croft Pascoe Forest (Cornwall)
Harwood Dale in Langdale Forest (Yorkshire)
Teindland Forest (Morayshire)
Wareham Forest (Dorset)
Wykeham and Broxa in Allerston and Langdale Forests (Yorkshire)

NUTRITION OF ESTABLISHED CROPS

Bramshill Forest (Hampshire)
Haldon Forest (Devon)
Tarenig Forest (Cardiganshire)
Wareham Forest (Dorset)
Wilsey Down Forest (Cornwall)

CONVERSION OF COPPICE

Alice Holt Forest (Marelands), (Hampshire)
Forest of Dean (Penyard), (Hereford)
Gardiner Forest (Wilts.)

PROVENANCE EXPERIMENTS

Scots pine:	Findon Forest (Easter Ross) Thetford Chase (Norfolk)
Lodgepole pine:	Achnashellach Forest (Wester Ross) Clocaenog Forest (Denbigh) Millbuie Forest (Easter Ross) Wykeham in Allerston Forest (Yorkshire)
European larch:	Coed y Brenin (Merioneth) Savernake (Wilts.) Mortimer (Hereford)
European and Japanese larches:	Clashindarroch Forest (Aberdeenshire) Drummond Hill Forest (Perthshire) Lael Forest (Wester Ross)
Douglas fir:	Glentress Forest (Peebles-shire) Laiken Forest (Nairnshire) St. Clement (Cornwall) Mortimer (Salop.)
Norway and Sitka spruces:	Newcastleton Forest (Roxburghshire) The Bin Forest (Aberdeenshire)
Sitka spruce:	Radnor Forest (Radnor)
Beech:	Queen Elizabeth Forest (Buriton, Hampshire) Savernake (Wilts.)

PRUNING EXPERIMENTS

Drummond Hill Forest (Perthshire)
Monaughty Forest (Moray)

PLANTING EXPERIMENTS ON SAND DUNES

Newborough Forest (Anglesey)

PLANTING EXPERIMENTS ON CHALK DOWNLANDS

Friston Forest (Sussex)
Queen Elizabeth Forest (Buriton, Hampshire)

ESTABLISHMENT OF OAK

Forest of Dean (Gloucestershire)
Dymock (Gloucester and Hereford)

POPLAR TRIALS AND SILVICULTURAL EXPERIMENTS

Blandford (Dorset)
Cannock (Stafford)
Doncaster (Yorkshire)
Dyfnant (Montgomeryshire)
Forest of Dean (Gloucester)
Gaywood (Norfolk)
Harling, Thetford Chase (Norfolk)
Hockham, Thetford Chase (Norfolk)
Quantock Forest (Somerset)
Stenton (East Lothian)
Wynyard (Durham)
Yardley Chase (Beds. and Northants.)

SPECIES PLOTS

Beddgelert Forest (Caernarvonshire)
Bedgebury Forest (Kent)
Crarae, near Minard Forest (Argyll)
Benmore Forest (Argyll)
Thetford Chase (Norfolk)
Wareham Forest (Dorset)

GENETICS

Propagation Centres

Alice Holt (Hampshire)
Grizedale (Lancashire)
Kennington (Berkshire)
Westonbirt (Gloucestershire)
Bush (Midlothian)

Tree Banks

Newton (Morayshire)
Alice Holt (Hampshire)
Rendlesham (Suffolk)
Bush (Midlothian)
Bradon (Wiltshire)

Seed Orchards

Newton (Morayshire)
Ledmore (Perthshire)
Drumtochty (Kincardineshire)
Archerfield and Whittingehame (East Lothian)
Alice Holt (Hampshire)
Bradon (Wiltshire)
Forest of Dean (Gloucestershire)
Rendlesham (Suffolk)

PATHOLOGICAL RESEARCH AREAS

Moorburnhead (Dumfries-shire):	Group dying of Conifers
Glenfinart (Argyll):	Group dying of Conifers
Haldon (Devon):	Resin bleeding of Douglas fir
Harling, Thetford (Norfolk):	Fomes annosus
Mundford, Thetford (Norfolk):	Bacterial canker of poplar
Queen Elizabeth Forest (Buriton, Hampshire):	Wound Protectants

ARBORETA

Bedgebury Pinetum (Kent)
Westonbirt Arboretum (Gloucestershire)

APPENDIX II

Staff of Research Branch as at 31st March, 1959

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Miss A. Brooks, M.B.E.	Senior Executive Officer

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R. Rendle	Higher Executive Officer

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M. Nimmo	District Officer
G. D. Holmes, B.Sc.	„ „
J. R. Aldhous, B.A.	„ „
J. Jobling, B.Sc.	„ „
J. M. B. Brown, B.Sc., Dip.For.	„ „
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R. Faulkner, B.Sc.	„ „
R. Lines, B.Sc.	„ „
D. W. Henman, B.Sc.	„ „

MANAGEMENT (Alice Holt)

F. C. Hummel, M.A., D.Phil.	Divisional Officer
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G. M. L. Locke, B.Sc.	„ „
A. J. Grayson, M.A.	„ „
D. Johnston, B.A.	„ „

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J. N. R. Jeffers, A.I.S. (Alice Holt)	Senior Scientific Officer
R. S. Howell (Edinburgh)	Scientific Officer

FOREST PATHOLOGY (Alice Holt)

T. R. Peace, M.A.	Divisional Officer
J. S. Murray, B.Sc.	District Officer
S. Batko, D.Ing.	Experimental Officer

FOREST ENTOMOLOGY (Alice Holt)

M. Crooke, B.Sc., Ph.D.	District Officer
D. Bevan, B.Sc.	,, ,,
Miss J. Davies, B.Sc.	Experimental Officer

FOREST GENETICS (Alice Holt)

J. D. Matthews, B.Sc.	District Officer
A. F. Mitchell, B.A., B.Ag.	,, ,,

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G. D. Kitchingman, M.A., Dip.For.	District Officer
H. Cruickshank, M.A., B.Sc.	,, ,,
I. A. Anderson, A.I.B.P.	Principal Photographer
Miss T. K. Wood, A.R.P.S.	Photographer

MACHINERY (London)

R. G. Shaw, B.A., A.M.I.Mech.E.	Machinery Research Officer

UTILISATION DEVELOPMENT (London)

E. G. Richards, M.C., B.Sc.	Divisional Officer
C. D. Begley, B.Sc.	District Officer
J. R. Aaron, M.A.	,, ,,

RESEARCH ON GREY SQUIRRELS (Tolworth, Surrey)

K. D. Taylor	Scientific Officer

APPENDIX III

List of Publications

The following papers by members of the Research Branch staff were published during the year ended 31st March, 1959.

Aaron, J. R.	*The Use of Home-Grown Timber in Packaging and Materials Handling.* Forest Record, For. Comm. London. No. 35.
Aldhous, J. R.	Polythene bags for movements of forest nursery stock. *Emp. For. Rev.* 38(1), 1959 (65–76).
Begley, C. D.	Notes on selected papers of the Seventh British Commonwealth Forestry Conference dealing with Utilisation. *Emp. For. Rev.* 38(1), 1959 (81–3).
Brown, J. M. B.	Forests and the Soil, *Biology and Human Affairs,* Lond. 23, 3 June 1958 (pp. 30–34).
Brown, J. M. B.	Natural Regeneration of Beech in Britain. *12th Congr. Int. Union For. Res. Organ. Oxford* 1956, *Papers,* Vol. 1 pp. 274–83.
Christie, J. M.	*Alignment Charts and Form Height Tables for Determining Stand Volumes of Conifers, Oak and Beech.* Forest Record, For. Comm. London No. 37 (1958).
Crooke, M.	Some aspects of forest entomology in Britain. *Proc. 10th Int. Congr. Ent., Montreal* 1956. Vol. 4, 1958 (233–39).
Edwards, M. V.	Use of triple superphosphate for forest manuring. *Rep. For. Res. For. Comm., Lond.* 1958 (117–30).
Edwards, M. V.	First report on an investigation begun in 1935 into Three races of European larch. *Rep. For. Res. For. Comm., Lond.* 1958 (164–83).
Faulkner, R.	Summer, autumn or spring lining-out? *Scot. For.* 12 (3) 1958 (127–34).
Faulkner, R.	Notes on Whittingehame. *J. For. Comm., Lond.* 26, 1957 (77–9) (Departmental).
Faulkner, R. and Aldous, J. R.	A review of nursery research: 1952–1956. *J. For. Comm., Lond.* 26, 1957 (97–112) (Departmental).
Gardiner, A. S.	Variation in bark characteristics in birch. *Scot. For.* 12(4) 1958 (191–5).
Grayson, A. J.	Road density in extraction planning. *Emp. For. Rev.* 37(3) 1958 (305–10).
Grayson, A. J.	Northerwood Conference. May 1st–4th, 1958. The management of coniferous crops. *Emp. For. Rev.* 37(4) 1958 (429–33) and *Forestry* 31(2), 1958 (194–201).

Holmes, G. D. and Buszewicz, G. — The storage of seed of temperate forest tree species. *Forestry Abstracts* 19 (1958) 313–22 & 455–76.

Holmes, G. D., Brown, R. M. and Ure, R. M. — Preliminary experiments on the use of Toxaphene and Endrin for the control of short tailed voles in young forest areas. *Rep. For. Res., For. Comm. London* 1958 (148–56).

Howell, R. S. and Kemp, D. — Comparison of methods of sampling for the measurement of moisture content in green timber. *Rep. For. Res. For. Comm., Lond.* 1958 (156–60).

Jeffers, J. N. R. — *Design of Poplar Experiments.* Forest Record, For. Comm., Lond. No. 38, 1958.

Jeffers, J. N. R. — *The collection, compilation and analysis of forest accident statistics.* FAO/ECE Jt. Comm. Working Tech. No. FAO/ECE/LOG/29, 1958.

Jobling, J. — *Methods in Assessing Poplar Experiments.* International Poplar Commission, FAO/CIP/CP/18 July, 1958.

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Forestry Practice. Revision of Bulletin 14.

Cultivation of the Cricket Bat Willow. Revision of Bulletin 17.

Elm Disease. Revision of Leaflet 19.

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