FORESTRY COMMISSION

REPORT ON FOREST RESEARCH

for the year ended March, 1963

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1964

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INTRODUCTION

By ANDREW WATT

Director of Research

Mr. James Macdonald, formerly Director of Research and Education, and latterly the Commission's Deputy Director General, retired during the latter part of the year on health grounds. It is most regrettable that Mr. Macdonald died not many weeks later. Apart from a spell before, during and immediately after the War, Macdonald's forestry life had been devoted to Research, and latterly as Deputy Director General he still retained the overall responsibility for Research. Macdonald's services to forestry have been written of elsewhere: suffice it to say here that his passing leaves a serious gap in the forestry world, and more particularly in the research field.

This Report follows closely the pattern set in recent years, and comprises contributions from all sections whose work has a research content.

Organisation

There were a number of important changes during the year. The post of Chief Research Officer was replaced partly by the creation of the post of Director of Research, and partly by creating a Conservator post at Alice Holt. Mr. A. Watt was transferred from Scotland toward the end of February to fill the former post and Mr. R. F. Wood was promoted at the beginning of April 1963 to fill the latter.

A re-organisation led to the transfer of the Management Section of Research Branch to the Commission's Headquarters, though the Section staff remain in their present stations at Alice Holt and at Edinburgh. Work Study Section, which had since its inception come directly under Headquarters, became the responsibility of the Director of Research. Here again the change involved no transfer of staff in the Section, whose office centre remains in Edinburgh.

Shortly after the end of the year under report the responsibility for Publications moved to the Research Directorate, and was combined with the Library and Documentation service.

Some indication can be gathered from the following pages of the common service content of the work of many of the Sections. In Statistics, for instance, there is a growing use of the service in management, planning and marketing.

Advisory Committee on Forest Research

The Committee met in October, 1962 in Oxford. In addition to normal business, the Committee had the opportunity of seeing the Commonwealth Forestry Institute and of discussing some of the research work going on there. The Committee also visited the Forest Products Research Laboratory of the Department of Scientific and Industrial Research at Princes Risborough, Buckinghamshire.

The Soils Sub-committee met in November 1962.

International Committees, Congresses, etc.

Mr. G. D. Holmes attended the Congress of the International Seed Testing Association held in Lisbon in May 1963.

Mr. J. D. Matthews, as leader of Section 22 of the International Union of Forest Research Organisations, attended the meeting of the Permanent Committee of the Organisation in Dublin, September 1962. He also took part in a preliminary meeting held by F.A.O. in Rome in May 1962 to prepare for the forthcoming World Consultation on Forest Genetics and Tree Breeding.

Mr. N. Dannatt of Work Study served on a joint F.A.O/E.C.E. Study Group working on the Multilingual Glossary of terms used in Forest Work Science.

Mr. R. F. Wood attended the Eighth Commonwealth Forestry Conference held at Nairobi, Kenya, June/July 1963.

Liaison and other Committees

The Research liaison committee with Nature Conservancy continued to be active, and preliminary discussions took place on ways and means of affording opportunities for side-effect studies by Nature Conservancy on the use of toxic chemicals in forest areas.

The Home-grown Timber Research Committee met three times, and the important work of linking desirable tree growth qualities with timber qualities was strengthened.

The Committees for the National Pinetum at Bedgebury and for the Westonbirt Arboretum each met twice during the year. An increasing amount of both Committees' time is devoted to the problems of providing for growing public interest in the arboreta.

Forest Research was represented on a number of other committees, both internal and international.

Liaison with other Bodies

Over and above the formal committees referred to, close contact was maintained with the University Forestry Departments, the Macaulay Institute for Soil Research, Rothamsted Experimental Station and a number of Research Stations whose work has an interest in, or is of interest to, forest research.

Visitors

Visitors to Alice Holt Research Station were numerous, and included Mr. E. P. Cliff, Chief of U.S.A. Forest Service, and Mr. Mihai Suder, Minister of Forest Economy, Roumania, accompanied by Mr. Ion Milescu (Forest Economy Section, General Secretariat of Council of Ministers).

Many visitors individually or in parties toured experimental areas in various parts of the country. Special mention may be made of a party of leading Finnish foresters and experts who studied experimental work on the use of fertilisers on poor mineral soils and peats in England and Scotland.

Students from the Forestry Faculties paid their customary visits to Alice Holt and field centres, and students from other Faculties in a number of Universities also visited experimental areas.

Facilities for research or education in research were made available to several people from abroad. Two British Council students (Mr. Ingvar Fystro, Norway, and Mr. S. T. Ollatoye, Nigeria) studied methods of seed extraction and seed testing at Alice Holt. Visitors from Turkey and Egypt were afforded facilities for research in Scotland.

Staff

Apart from the organisational changes noted above, there are a number of other changes to record.

Forest Soils Research was hived off from Silviculture and became a separate section. Seed also became a separate section, though continuation of the closest liaison with Silviculture and Genetics will be maintained. Mr. G. D. Holmes, after many years on Silvicultural research, transferred to the field early in 1963. Mr. R. M. G. Semple moved from Library and Documentation duties to lead the Silvicultural Section for the South of Britain. Dr. Binns came from the Macaulay Institute for Soil Research, and leads the new Soils Section.

A change that will take place before this Report appears, arises from the appointment of Mr. J. D. Matthews to the Chair of Forestry in Aberdeen University. Mr. Matthews has been the leader of the Forest Genetics Section since its beginning. The work of the section is well known at home and abroad, and it says much for the solid foundation established under Mr. Matthews' direction that the work will continue soundly.

Changes in organisation and in personnel can lead to breaks in continuity. Difficulties are almost inevitable in such circumstances, but sensible co-operation has enabled the changes to be made with the minimum of upset.

SUMMARY OF THE YEAR'S WORK

By R. F. WOOD

Conservator, Research Directorate

The Report is in very much the same form as last year's. A number of changes in organisation and staff have been noted in the Director's Introduction; these are to some extent reflected in the text of the report by changes in authorship and in the relative weights of subject matter. The re-allocation of projects frequently enforces a salutary period of digestion, which is not to be confused with quiescence.

Management, Utilisation Development, and Machinery are parts of the Headquarters Organisation and not the Directorate of Research, but it is convenient to publish all activities in research and development in this Report.

The Season

The spring and summer of 1962 were rather poor, relieved somewhat by the absence of late frosts of any serious consequence. In Scotland the whole growing season was cool and often wet; in England and Wales, however, June was unusually dry. August and September were cool and wet over the whole country.

The outstanding feature of the season was, however, the long exceptionally cold spell commencing round about Christmas 1962 and lasting with no significant breaks till early March. This gave England and Wales the most severe winter since 1740, with over two months of continuous frosts, exceptional snowfalls and minimum temperatures falling below zero in many places. Scottish conditions were similar except that the north-west escaped the heavy snowfalls.

Extremely severe conditions for young trees were experienced over very wide areas, the worst circumstances being in exposed hill country with relatively little snow coverage to foliage. Damage ranging from browning to dieback of substantial proportions of the crown in young trees was of common occurrence in Sitka spruce and Western hemlock. This type of winter, which according to some experts may now be expected to occur at greater frequencies than in the first half of the century, may well give us cause to reconsider some of our ideas on provenance of seed, and perhaps also our concepts of the elevation limits for planting.

PART I

This part of the report describes the activities of various sections of the Forestry Commission Research Branch, and of certain sections in the Headquarters Organisation whose work has a research content. Brief summaries are given below.

Forest Tree Seed

The central refrigerated seed store at Alice Holt is described, and statistics are given for the year's movements of seed. Plans for the construction of a seed extraction plant to serve England and Wales are well advanced. The number of seedlots tested continues to mount, due mainly to the increase in home seed collection.

Work on the improvement of seed testing methods continues, much of it being done in conjunction with the International Seed Testing Association. Research in seed storage has yielded promising results with beech mast, which it now appears can be stored under conditions suited to conifer seed for two years while retaining a useful proportion of viable seed.

Nursery Investigations

The collaborative programme of research in nutrition with the Rothamsted Experimental Station continues, but progress reports are suspended till the publication of the results obtained in the period 1945-62.

Experiments on the control of weeds and on cold storage continued to be the main items in the Forestry Commission's programme. Atrazine and propazine were the most promising alternatives to simazine for weed control among transplants. Diuron and neburon were screened as post-emergence residual herbicides on seedbeds. The former damaged the crop but the latter did no damage and gave good control of weeds.

Experiments and field trials on cold storage of seedlings demonstrated the value of the technique and added to the information on species suitable for storage by this technique.

Some observations were made on new formulations of inorganic fertilizer put up in granules with water-resistant coatings.

Experiments on protection against bird damage to seedbeds failed to indicate any new technique that would replace the present costly system of netting.

Silvicultural Investigations in the Forest

Work on the afforestation of difficult sites in the northern isles, at high elevations and on the upland heaths is described. Cultivation and manuring are the principal subjects of investigation on the heaths. The advantages of complete ploughing instead of single furrow ploughing at intervals are being specially studied.

The drainage of sites before planting, and also the intensification of drainage in pole stage crops, have had particular attention during the year. The problems have been considered from the aspects of depth and spacing of drains, their alignment and the machinery required to make the drains most effectively. In the north experiments on deep peat are being planted and results of older experiments on mineral soils are being investigated.

In the south, drainage experiments have been concentrated on heavy clays. At the experiment at Halwill (Devon) flowmeters and boreholes have been installed. Big differences in borehole levels have been recorded since draining.

On the subject of nutrition, a great deal of evidence is being accumulated on the effects of fertilizers, firstly by means of foliage analysis and secondly by measuring the resulting height or girth increment of the tree crops. New experiments have been established; one in collaboration with the Nature Conservancy on blanket peat over the drift soil on the slopes of Beinn Eighe in Wester Ross, and another comparing the effect of phosphate applied by a newly designed machine with the customary methods of hand application. Some details are given of the great effect of combined N, P, K fertilizer on a young and partially checked pine and spruce crop.

A survey of the use of fertilizers in Commission forests has shown a steady increase in the use of phosphate within the last three years. Most is applied within the first three years after planting, and ground mineral phosphate is still the most popular form. Considerable variation in practice was revealed, the basis for some of the differences being by no means clear.

In the increasingly urgent problem of the artificial regeneration of even-aged spruce crops, particularly Sitka spruce, the preliminary results of an experiment comparing different sizes of felling area suggest that damage by windthrow along the margins is least in the largest area felled, when calculated on the number of trees blown down or broken by area. Methods of restricting the extension of windthrow by treatment of exposed margins are being investigated. A preliminary survey of the areas proposed for clear felling for the pulp mill at Fort William has been carried out in order to assess the problems which will require investigation. The manuring of young second rotation crops with phosphate has given no early responses and the use of nitrogen to give the plants a short-term 'boost' in order to overcome the very rapid reinvasion of weed growth is being tried.

Experiments comparing differing degrees of thinning of Japanese larch preparatory to underplanting are being established in Scotland and Wales.

Further work has been done on brash disposal by means of mechanical 'choppers'. The method shows much promise; development work on a suitable machine has been carried out.

A suitable seed trap has been designed for studies connected with natural regeneration and seed production generally.

A few further trial plots of Leyland cypress *Cupresso-cyparis leylandii* have been planted and detailed research into the origins and dissemination of the clones of this interesting hybrid has been conducted.

Some cautionary comments are made on the behaviour of the two *Nothofagus* species, *N. procera* and *N. obliqua*, which have recently shown a number of disquieting symptoms.

The results of the Scots pine provenance experiments planted on the west coast of Scotland, with an inland control, are described. New experiments comparing provenances from the whole range of the Black pine, *Pinus nigra*, which seems to be resistant to atmospheric pollution, are being planted in the Pennines. Provenance work on Black pine is also of interest in connection with calcareous sites in the south. A great deal of work has been carried on in the Lodgepole pine provenance experiments, as large areas of this species are now being planted and the variation within the species is extremely great. Recent work with Western hemlock, Sitka spruce and Western red cedar is noted.

Work on the spacing of plants in afforestation and on pruning is being continued.

Herbicides studied in the forest have included ammonium sulphamate, 2,4-D, 2,4,5-T and certain residual herbicides. Ammonium sulphamate is clearly of value against *Rhododendron ponticum*, which is comparatively resistant to most herbicides. Work on 2,4,5-T is mainly concerned with methods of use. Aerial applications of 2,4-D have been made in pine plantations to control heather. Some attention has been paid to residual herbicides in regeneration areas.

Further work has been done on temporary deer fences using various types of synthetic fibre netting.

In the assessment of atmospheric pollution by sulphur dioxide it appears that zinc plate gauges may be nearly as efficient as the less convenient lead oxide types.

Further studies of the effects of wind have been carried out; models developed from the previous years experience of the behaviour of trees in the wind tunnel have been used in studies at the National Physical Laboratory. More observations have been made on the effects of site and root habit on stability by the 'pulling over' technique. This has been used to investigate the effects of incorrect planting methods applied experimentally some thirty years ago.

Special studies are being made in Sitka spruce crops showing a marked decline in vigour in the early pole stage.

Poplars and Elms

Assessments of the major poplar trial plots confirms that certain balsam and balsam hybrid clones are faster growing than any of the Hybrid black varieties in use in the country; the differences are specially marked in the north.

In one of the earliest-planted spacing experiments, reductions in girth increment due to close spacings of eight feet have been noted nine seasons after planting, but are not yet apparent at spacings of fourteen feet.

Vernier girth bands have been used to study the effects of different pruning intensities on girth increment of poplars throughout the season.

Studies on bacterial canker of poplar and varietal susceptibility continued.

The elm clonal collection now totals 76 clones, 49 of which are selections of 'plus' trees in Britain. Special attention is paid to elms of known or reputed high timber quality. Further work has been done on mist propagation of cuttings. Studies of age and type of plant have been started.

A number of clones have been added to the Dutch elm disease trials.

Forest Ecology

The study of the Black pine, *Pinus nigra*, continued to be the main item on the Ecologist's programme, but an ecological survey of the plantations on the highly exposed coastal sands near Dunnet Head, Caithness, was also undertaken.

Forest Soils

Soil moisture studies in woodlands have featured prominently in the work of the year. In connection with soil moisture work, further measurements of girths and electrical resistances of tree stems have been made.

Observations on two Garnier Gauges have been continued throughout the year in order to measure potential evaporation.

Increased attention has been paid to drainage problems during the year with the improvement of existing practices in mind. Preliminary work has involved studies of drain spacing and slopes by means of models. Instruments have been developed to measure water flow in forest drains and work is proceeding on other devices to interpret the results obtained.

Routine analytical work on plant and soil material continues on an undiminished scale. Advances have been made in the design of equipment for atomic absorption spectroscopy which is a promising new method of chemical analysis.

Forest Genetics

The staff of the Genetics Section have continued their work on the improvement by selection and breeding of the two-needled pines, the larches, Douglas fir, the spruces and beech; the major emphasis being placed on the breeding of Scots and Lodgepole pine and Sitka spruce. Good progress was made in converting seed sources into seed stands and more than 800 acres have been wholly or partially treated.

The procedure for selecting Plus trees of Sitka spruce has been revised and the field assessments are now being recorded on punch cards. The number of Plus and Special trees of all species is now 3,439. More than half of these trees have been propagated by grafting or the rooting of cuttings, and the resulting clones have been planted in Tree Banks. The Tree Banks are proving of great value in developing the programme of controlled crosses and progeny testing.

There are now 204 acres of seed orchards, 176 acres being maintained by the Forestry Commission, while 28 acres are on private estates. An experiment in a Scots pine seed orchard has revealed the value of hop waste in maintaining the growth of grafted plants and increasing the production of female flowers.

Forest Pathology

In the Pathology Section, work on death and decay caused by *Fomes annosus* concentrated particularly on field trials of chemicals to replace creosote as a stump protectant, and on the development of a technique of biological control using the competing fungus *Peniophora gigantea.* Among the chemicals, the best results were obtained with sodium nitrite.

A study of extraction damage and associated decay was begun, and the losses in some forests through rot fungi entering extraction wounds were found to be considerable. Work was also begun on Drought crack in the Silver firs, *Abies* spp.

A survey was made of areas of Scots pine affected by Resin top disease (*Peridermium pini*). Experimental plots of *Pinus strobus* were examined, and evidence obtained of the importance of nursery infection in the epidemiology of the White pine Blister rust disease (*Cronartium ribicola*).

In the nursery, experiments were continued on the control of Needle blight (*Didymascella thujina*) of Western red cedar, using cycloheximide and its derivatives, and some work on Grey mould (*Botrytis cinerea*) was also carried out.

Investigations (some in conjunction with other bodies) continued on Blue stain in pine, Damping-off in nurseries, Bacterial canker of poplar, and other diseases and disorders.

Forest Entomology

Pupal counts of the Pine looper moth, *Bupalus piniarius*, showed low figures in all pine forests except Cannock Chase, where populations seemed likely to reach a critical level in 1963. Studies of parasitism by *Cratichneumon nigritarius* continue.

Studies of the sawfly *Anoplonyx destructor* continue. Work has started on fluctuations in the population of the seed-fly *Megastigmus spermotrophus* in relation to coning in Douglas fir. Work on protection of plants against the Pine weevil *Hylobius abietis* continues. The ambrosia beetle *Trypodendron lineatum* has suffered a marked decline in population, and further studies are in abeyance. The Clay-coloured weevil, *Otiorrhynchus singularis*, has appeared in unusual numbers and done serious damage to transplants at a few forests.

Mammal Research

Work on Grey squirrel continues in collaboration with the Infestation Control Division of the Ministry of Agriculture. Poisoning trials with warfarin have given promising results in Scotland. Cage trapping in the damage period (May to July) is being studied.

Work has started on the biology of deer in relation to control measures. Further work has been done on chemical repellents, particularly with respect to stickers and the persistence of repellents. Work is also being done on synthetic fibre netting and electric fences.

Surveys are being made by the use of questionnaires to obtain information on the amounts and nature of damage caused by various mammals and birds in forests and nurseries.

Management

The greater part of the work in the year has been in the provision of aids and techniques for planning.

Working Plans

Field work was completed over 163,000 acres, and is now being carried on over 280,000 acres. A special survey of hardwood pulp resources was undertaken in the region supplying the Sudbrook mill, near Chepstow in Monmouth.

Economics

Advisory work has outweighed research. Technical aids to planning have been prepared on the economics of species choice, rotations and roading. Assistance has been given to the Land Use Study Group. A study of developments in stumpage values over the last half century has indicated a rise of values in real terms of 1½%, compound. Investigations into labour productivity in recent years has shown an average increase of 2¼% per annum.

The economics of replacement of low productivity crops such as larches and coppice has been studied. It has been shown that the case for early replacement of these is not as strong as commonly supposed.

Mensuration

The major project has been the analysis and revision of existing yield data for the production of new Forest Management Tables. The basic classification of yield in these tables will be by maximum mean annual increment. The Tables will show the development of crops under what is now considered to be the optimum pattern of thinning, i.e. that which gives the greatest girth increment compatible with maximum volume increment per unit area.

Work Study

The section worked throughout 1962 on the four assignments reported on last year, but had commenced two others by early 1963.

Considerable progress was made in the development of new logging techniques for the Scottish pulpmill project, a major improvement in methods being the successful employment of a Norwegian double drum winch. A series of publications is in hand on production work, the first being published during the year.

The section is increasingly engaged in the planning and development stages of new timber-using industries and the introduction of new machinery, rather than in examination of traditional working methods.

Work on brashing of spruce was completed and written up for publication. The time study of hand weeding and calculation of standard times has demonstrated that a series of subjective assessments of site conditions will give a valid estimate of the standard time as a basis for equitable piece rates.

Training and dissemination of information by courses, lectures and reports occupies a great deal of the time of all the Work Study officers.

Utilisation Development

The joint programme of research on home grown timbers with the Forest Products Research Laboratory has continued. Other work in conjunction with the Laboratory has included studies of accelerated air drying of sawn timbers and pitprops.

Studies on the out-turn in conversion of low quality oak boles have been started. Further work has been done in connection with the use of wood flakes as animal bedding litter.

Machinery Research

The third Forest Machinery Exhibition was held at Edinburgh in June 1962 and was very well attended. The general improvement in tractor design, particularly the increase in power available at the power take-off, is very welcome. Development work has taken place on field battery chargers for quick engine starting, lorry loading, winching, deep cultivation, drain cleaning and a number of minor improvements of existing machinery. New machines likely to be of use in forestry have been examined and tested, including an interesting portable sawbench of French origin.

Design and Analysis of Experiments

A Ferranti Sirius computer has been installed at the Forestry Commission Research Station at Alice Holt, and much of the work of the Statistics Section over the past year has been concerned with the necessary preparatory work involved in the installation of the machine and in re-organisation of the Section to make the best use of the computer.

The usual service of advice on the design and analysis of experiments, the analysis and interpretation of numerical information, and research into the application of statistical methods and electronic computing to problems of forest research and management has nevertheless been maintained.

Photography

Over 14,000 slides were loaned during the year. It is hoped that the preparation of standard sets for schools, Conservancies, etc. will reduce the demands on the central collection.

There is a strong demand for films, and it is proposed to re-commence a modest film programme, confined initially to record or training films. The section is increasingly concerned with advisory work, document, plan and map reproduction. A number of aids for the preparation of diagrams, graphs, plans etc.

have recently become available, and will result in better standards of presentation.

Library

The Library continued to give its usual services. As noted by the Director in his introduction, the Library has now been joined with Publications. Owing to the re-organisation, no detailed report on the Library side is given.

PART II

In this part will be found progress reports on research work supported by Commission grants at Universities and other institutions.

Research on Scottish Forest and Nursery Soils

Dr. W. O. Binns and Dr. J. Keay of the Forest Soils Section, Macaulay Institute, Aberdeen, have continued their investigation into the nutrition of trees on sand and peat. At Culbin fertilization of young Corsican pine trees with nitrogen has doubled their rate of growth. Results from a fertilizer trial on 76-year old Scots pine trees growing on gravel have shown that good responses can be obtained from N and P.

Physical conditions limiting root development in peat are also being examined, with particular reference to the oxygen requirement of trees.

Experiments in the Pathology of Sitka Spruce Seedlings

Dr. G. A. Salt of Rothamsted Experimental Station reports on investigations on seed and soil treatment, a continuation of studies briefly described by Mr. Ram Reddy in the 1962 number of the Report on Forest Research.

Partial soil sterilants substantially increased growth of Sitka spruce seedlings and sometimes increased numbers, whereas seed treatments had no effect on growth but usually increased numbers, even in partially sterilized soils. 'Mylone' was comparable with formalin as a partial sterilant, with the advantage that it can be applied to soil as a dust.

Nutrition Experiments in Forest Nurseries

Miss Benzian of Rothamsted Experimental Station has now completed the account of the nursery nutritional experiments initiated by the late Dr. E. M. Crowther, and carried out as a collaborative project between Rothamsted and the Forestry Commission. The publication will appear as a Forestry Commission Bulletin. A second Bulletin will deal with the complementary forest experiments.

Here Miss Benzian reports on one item of work of current interest.

Norway spruce and Sitka spruce were compared in fertilizer experiments at Bagley near Oxford and Wareham in Dorset between 1959 and 1962. In all four years fertilizer responses for *seedlings* were similar for both species.

Whereas *transplants* of both species had also responded similarly between 1959 and 1961, in July 1962 (after a cold and windy spring and a dry June), Norway but not Sitka spruce developed a rusty-red scorch on many plots treated with superphosphate and potassium chloride; the scorch was particularly severe on ammonium sulphate-treated plots, which had become very acid. 'Nitro-chalk' either lessened the scorch or had no effect; magnesium sulphate caused no harm.

The Action of Enzymes on Plant Polyphenols

Work at the Dyson Perrins Laboratory, Oxford, on the protein-fixing constituents of plants is described in a further report by Miss Sheila Bocks and Professor B. R. Brown of the Laboratory, and Dr. W. R. C. Handley of the Department of Forestry, Oxford University.

Biology of Forest Soil

Dr. G. W. Heath of Rothamsted Experimental Station has continued his studies on the breakdown of oak and beech litter and the role of earthworms.

Rate of disappearance of beech and oak disks on soil with and without earthworms are shown graphically. In an attempt to find out what causes differences in rate of disappearance, experiments have been started with leaves of different age and from a variety of plant species. Tests *in vitro* of the digestibility of oak and beech by rumen organisms showed oak to be twice as digestible as beech.

Studies on the Mycology of Scots Pine Litter

At the Department of Forestry, University of Edinburgh, Dr. A. J. Hayes has commenced work on the role of fungi in the breakdown of the litter of Scots pine. This study is in many ways complementary to the investigations of Dr. D. R. Gifford on the mite fauna of forest litter. The ultimate object of Dr. Hayes' studies is to determine the precise pathways of decomposition and end products of each substance occurring in the needles. Fungi isolated from Pine litter so far include species of *Absidia*, *Mortierella*, *Mucor*, *Botrytis*, *Cephalosporium*, *Penicillium*, *Rosellinia* and *Trichoderma*.

Chemical Changes in Forest Litter

Dr. J. Tinsley and Miss Aileen Lennox (succeeding Dr. Hance) of the Department of Soil Science, Aberdeen University, present a second report on the investigations proceeding concurrently on plots in Bramshill Forest (Hampshire) and in the laboratory at Aberdeen.

Following the application of urea, ammonium sulphate and ammonium phosphate to unlimed and limed field plots and microlysimeters in March 1962, at rates of 50, 100 and 200 lbs. of nitrogen per acre, samples of drainage water have been collected at intervals for analysis, and samples of the organic matter were collected from each plot in October 1962 and April 1963.

Treatment with urea caused considerable amounts of organic matter to dissolve in the drainage water of both the field microlysimeters and experimental columns set up in the laboratory, whereas most of the nitrogen applied as ammonium sulphate or ammonium phosphate passed directly into the drainage water with comparatively little dissolved organic matter.

The mean nitrogen content of the organic matter passing a 2 mm. sieve from the unlimed plots was 1.45 per cent, and from the limed plots 1.50 per cent, but the differences between the various nitrogen treatments were too small to be significant. About 21 per cent of the organic material from selected unlimed plots was found to dissolve in boiling anhydrous formic acid containing 10 per cent acetylacetone and was recovered by precipitation with di-isopropyl ether. This fraction was considerably enriched in nitrogen and polysaccharide.

Hydrological Relations of Forest Stands

At the Commonwealth Forestry Institute, Oxford University, Dr. L. Leyton and Dr. E. R. C. Reynolds report that the initial investigations concerned mainly with the development of methods for measuring the different phases of the water cycle in forests are now reaching their conclusion. Suitable techniques have been worked out for interception, throughfall (including stemflow), soil moisture distribution and evaporation from the forest floor. Much valuable information has been obtained especially with regard to the hydrological significance of the redistribution of intercepted water on the forest floor. Some improvements have been made in the heat flow technique used for measuring transpiration via sap flow rates in the stems; further research however, is essential to solve the problem of the absolute accuracy of rain gauging above forest stands.

More detailed investigations have shown that certain conifers can absorb water intercepted by the foliage, and that the surfaces of the needles may be specially adapted to this end.

The Study of Fire Spread in Forest Fires

Dr. P. H. Thomas and Mr. D. L. Simms of the Fire Research Organisation, Boreham Wood, Hertfordshire, have continued fundamental investigations into fire spread. Still air conditions have been studied, and the heat balance equations derived will be used to supplement earlier work on the effects of wind on fire spread.

Oak Population Studies

Two further reports are rendered by Mr. J. E. Cousens and Mr. D. C. Malcolm of the Department of Forestry, Edinburgh University.

The variation of some important diagnostic characters of *Q. petraea* (Matt.) Liebl. in Eire and *Q. robur* L. in eastern England has been studied. In Eire, *petraea* populations are generally homogeneous (unlike those in Scotland) and there is evidence of only a little introgression there. In England *robur* populations sampled were only a little less heterogeneous than in Scotland, and it is still not possible to define *Q. robur* L. satisfactorily.

Continuing the Oakwood Survey in Scotland, the pilot survey to locate populations of *Q. petraea* in Galloway was begun. After preliminary historical investigation the number of stands in the region which were to be included in the survey was reduced to 170, covering approximately 3,700 acres. Of these 35 were examined and collections made in 15. Only 3 proved on analysis to be entirely homogeneous *petraea* populations.

Physiological Studies in the Rooting of Cuttings

Professor P. F. Wareing and Mr. N. G. Smith, Department of Botany, University College of Wales, Aberystwyth, continue their basic studies on the rooting of cuttings.

Experiments have been carried out with leafy ('softwood') cuttings of *Populus robusta* to investigate the effects of various factors on their rooting. It was found that whether the cutting is actively-growing, or dormant, has little effect on its rooting-ability, provided mature leaves are present. Under long days more roots are formed than under short days. No evidence could be obtained of any progressive trend in rooting-ability throughout the season with cuttings maintained under constant long day conditions, but the rooting of leafy cuttings appears to be reduced in late September. The orientation of the parent shoots has a marked effect upon the subsequent rooting of hardwood cuttings, those from vertically-growing shoots producing more roots than those from horizontally-trained shoots.

Effects of Stump Treatments on Fungal Colonisation of Conifer Stumps

Mr. D. Punter, Botany School, Cambridge University, completed his studies on stump treatments in September 1962. Treatments of high general fungitoxicity, e.g. creosote, do not appear suitable on sites where *Fomes* is already established in root systems. Under such circumstances treatments such as sodium nitrite are to be preferred, since they may prevent surface colonisation by *Fomes* without excluding competitive saprophytes.

Studies of Tit and Pine Looper Populations at Culbin Forest

Dr. Myles Crooke, Department of Forestry, University of Aberdeen, has commenced large-scale experiments in the controversial field of control of insects by birds.

Two study areas, each about 200 acres in extent, have been selected in the pine plantations of Culbin Forest for investigations on the interactions of tit and Pine looper populations. Preliminary work has shown that prior to the application of any 'treatment' (essentially, the provision of artificial nest sites in one plot in an attempt to increase tit numbers there) the two plots are broadly similar in terms of the numbers of tits and loopers which occupy them. Densities of Pine looper pupae in spring 1962 were quite high, the two plots having mean counts of 3.5 and 4.3 pupae per square yard. The densities of the two species of tits which occur at Culbin were low. Estimates of the number of breeding pairs of Coal tits varied between 3 and 6 per 200 acres, depending on the method of estimation, whilst Crested tits were scarcer than this.

Dieback Disease of Corsican Pine

Mr. D. J. Read, Department of Botany, Hull University, has continued his study of the factors responsible for this disease, and has shown that there is an interesting connection between site topography and proneness to the disease, which is constantly associated with the fungus *Brunchorstia pinea.*

PART III

Part III consists of papers on a variety of subjects; completed studies, interim reports on long term projects, applications of particular methods etc. Most of these are contributed by members of the staff of the Research Branch. It is considered that in future this part of the report will be best used to carry papers of the nature of comprehensive reviews of continuing projects. Accounts of finished work appear more appropriate for other modes of publication, but it may often be convenient to publish papers on methodology here.

In this issue, Mr. R. Lines reports on the assessments, after the sixth growing season, of a series of provenance experiments in Scots pine from seed sources in eastern Scotland. Mr. Lines has also a paper on the results of early experimentation on the provenance of Sitka spruce.

Mr. J. Atterson describes an extensive series of experiments in which stocks produced by undercutting seedlings are compared with those of similar age produced by conventional transplanting, and also with undisturbed seedlings.

Mr. J. N. R. Jeffers has two papers. The first describes an interesting application of the modern electronic computer in the production of a catalogue for the Westonbirt Arboretum. The second presents the result of a statistical analysis of the age and length of service in the industrial grades in the Forestry Commission.

Miss J. J. Rowe and Mr. H. G. M. Dowden describe a use for the National Grid reference system in which, by a modification of the normal conventions, Grid references can be used as co-ordinates in investigations involving the use of the computer.

Dr. D. R. Gifford, Department of Forestry, University of Edinburgh, contributes in summary form the principal results of a study in soil microarthropod populations, being the subject of a thesis submitted for the degree of Ph.D. at Edinburgh University.

PART I

Reports of Work carried out by Forestry Commission Research and Development Staff

FOREST TREE SEED

By G. BUSZEWICZ

Seed Storage and Supply

The central seed store at Alice Holt consists of three refrigerated chambers, two having a constant temperature of 36°F (2°C) and one of 20°F (-5°C). The higher temperature is used for the main bulk of seed which is stored for short periods not exceeding 3 to 4 years, and the lower temperature for seed to be kept for longer periods, and for the more difficult genera such as *Abies* and *Tsuga*. (See Plate 2 in central insert).

The total capacity is about 45,000 lbs of conifer seed, that is, over three times the average annual requirement. These facilities are being used to implement the policy of holding two years' requirement, and space allows storage of larger quantities so that advantage can be taken of especially good seed years when collection is easy and seed of high quality.

The seed is stored in tin-plated cans lined with a 500 gauge polythene bag to provide a safeguard against undetected rust pinholes or damage to the can. The capacity of the can is from 8-20 lbs. according to species, i.e. seed size and density. These containers are stored in specially constructed racks, and each chamber can accommodate over 700 cans.

On arrival each seed lot is checked for moisture content, and if too moist for storage is passed through a seed drier; the moisture content being brought into the range 6 - 8%. After drying, the seed is mixed to ensure homogeneity. In some cases, to reduce unnecessary work in recording, sampling and testing, certain categories of seed from neighbouring origins are mixed to produce larger uniform lots.

Whilst in store the quality of each seed lot is checked annually. For this purpose small representative samples are taken at random and sent to the laboratory for analysis. The refrigerated store has been in operation for five years. Several seed lots have been stored for this time and there has been no evidence of any substantial deterioration.

During the year under review 6,500 lbs. of conifer seed were used by the Commission, and 4,300 lbs. sold to private forest owners and the nursery trade. In the five years during which the refrigerated store has been in operation the amount of seed sown by the Commission has declined steadily from 14,000 lbs. to 6,500 lbs. While the out-turn of seedlings has fluctuated rather widely in this period, there has certainly been no commensurate decline in production, and it appears likely that maintenance of high viability under good storage conditions is effecting considerable economies.

The total seed stock held at the end of the sowing season was over 24,000 lbs. and consisted of over 400 different lots. Stocks of main species were as follows:

Over three years' supply:	Corsican pine; Sitka spruce; Douglas fir.
Two years' supply:	Scots pine; Norway spruce; Western hemlock; *Abies grandis.*
One year's supply:	European larch; Western red cedar; Lawson cypress; *Abies nobilis.*
Less than one year's supply:	Lodgepole pine; Japanese larch; Hybrid larch.

The 1962-63 season did not give a good home crop, and only 600 lbs. of conifer seed were collected, the largest amounts being from selected stands of Scots pine (138 lbs.); Hybrid larch (161 lbs.); and Lawson cypress (175 lbs.). Of the main hardwood species only 3,000 lbs. of acorns and 75 lbs. of beech nuts were collected, and to meet programme requirements 10,000 lbs. of acorns and 2 million beech seedlings had to be imported. The dependence on foreign seed sources is not wholly satisfactory, and efforts are being made to increase home supplies as quickly as possible. At present the home sources are sufficient for Scots pine, Corsican pine, Hybrid larch and Lawson cypress, but for all the remaining species we are still largely dependent on import. In the last season over 9,000 lbs. of conifer seed were imported.

Seed Extraction

Plans for the construction at Alice Holt of a new seed extraction plant for England and Wales are well advanced, and it is hoped that the plant will be completed in January 1964.

The plans provide for temporary storage of cones in self-stacking wooden pallets, low temperature pre-drying of cones in pallets, high speed final drying and opening of cones in the main kiln, cleaning and grading of extracted seed. The final product will be clean and graded seed ready for storage, sale or sowing. The new extractory will be equipped to deal efficiently with an annual programme of 1,000 to 6,000 bushels within the extraction season of 18 weeks. Elasticity and low labour requirements are the aim, and the capacity is divided between a drum kiln (for seed lots of 10 bushels or more) and small drawer-type kilns (for lots of less than 10 bushels). All kilns will have draught ventilation for maximum control and efficiency of cone drying.

Seed Testing

Seed testing work continues to increase as shown in Table 1 below:

TABLE 1

NUMBER OF TESTS CARRIED OUT 1960-1963

Seed Testing Year	No. of samples received	No. of Tests Completed						
		Purity	Seed Size	Germ-ination	Tetra-zolium	Moisture Content	Others	TOTAL
1960/61	709	404	470	1,414	22	427	30	2,767
1961/62	911	333	380	1,428	57	711	92	3,001
1962/63	1242	637	678	1,555	152	926	179	4,127

The marked increase in number of tests during 1962/63 was largely due to the developments in home seed collection; in general, these seed lots are small compared with imported seed lots.

About 20% of the tests were carried out as part of the experimental programme, and some two dozen tests were performed for private forest owners.

Research

Work on the improvement and standardisation of test methods was continued, both by experiments and by analysis of data collected during the course of routine service. A considerable part of this work was in co-operation with the International Seed Testing Association in preparation for the revision of the International Seed Testing Rules. This will take place in 1965 and the main items in which the Alice Holt Seed Laboratory is concerned are:—

(i) *Revisions of germination prescriptions.* The main task here is to scrutinise the present prescriptions in order to make all necessary corrections and additions to the existing rules.

(ii) *Seedling evaluation.* Experience has shown that in seedling classification there is a wide variation between stations. More detailed description of abnormal seedling types are considered essential for uniform classification.

(iii) *Excised-embryo tests.* Many seed analysts consider this a reliable method for testing various slow germinating species, including those for which the tetrazolium method is now prescribed, and in order to compare the merits of this with biochemical and other methods referee tests for several species are involved.

(iv) *Moisture content tests.* The work of calibrating the oven method, by use of the Toluene Distillation system, was continued to facilitate the prescription of methods for the more important species.
(See Plate 3 in central inset).

Pretreatment of Seed

Hydrogen peroxide has been reported to have stimulating properties on germination and subsequent seedling growth. It has also some fungicidal effect, and may be of value as a seed surface sterilant. Some preliminary tests have been carried out on *Abies nobilis* seed with concentrations and periods of immersion. Results are being analysed.

Seed Storage

In seed storage investigations most attention has been paid to beech nuts and *Abies* seed which appear to have the shortest life-span of our main species. Studies of the longevity of beech seed under contrasting storage conditions were continued into the third year. The experiment started in 1960/61 is a continuation of the earlier work reported in the Report on Forest Research for 1961, pages 117–126. The storage conditions include temperatures of –10°C, –5°C and +3°C, with seed moisture content fixed at levels of 10, 15 and 20% in air-tight containers. The experiment is carried out on 3 different seed lots and the test results are summarised in Table 2 overleaf.

TABLE 2

GERMINATIVE CAPACITY OF BEECH SEED FOR STORAGE PERIODS UP TO 29 MONTHS

Seed Lot.	Storage Temp.	Moisture Content	Germination % by months of storage								
			3	5	8	12	16	20	23	26	29
		%									
A	3°C	10	88	85	87	88	75	57	50	56	40
		15	88	88	67	31	2	0	0		
		20	88	93	79	63	33	7	0		
B	3°C	10	95	74	69	68	37	47	19	19	5
		15	95	82	66	14	0	0			
		20	95	77	41	2	0	0			
C	3°C	10	92	85	77		76	54	50	22	28
		15	92	98	87	84	68	3	1	0	
		20	92	93	81	63	39	7	1	0	
A	-5°C	10	88	85	88		82	79	59	73	69
		15	88	88	83		75	47	8	7	2
		20	88	93	86		87	58	25	11	2
B	-5°C	10	95		84		75	81	59		63
		15	95	82	76	19		5	0		
		20	95	77	73	23	17	0			
C	-5°C	10	92	85	84		69	70		59	68
		15	92	98	91	84		47	47	19	15
		20	92	93	86	79		58	27	3	0
A	-10°C	10	88	85	85	92		79	81	73	73
		15	88	88	88	73		76	35	23	17
		20	88	93	88	82		52	46	31	18
B	-10°C	10	95		87	65		68		51	61
		15	95		80	32	29	14	3	2	0
		20	95		89	32	21	10	0		
C	-10°C	10	92	85	84	83		87	85	81	69
		15	92	98	94	91		65	61	39	35
		20	92	93	96	91		73	57	38	40

Results of these tests confirm the previous indications that beech seed can withstand drying to the level of 10 per cent without injury. Hence it would be possible to store the seed in conditions similar to those employed for conifer seed. In order to check the plant production, small amounts of the seed with the highest viability after 2½ years storage were sown in the nursery.

The storage experiment with *Abies nobilis* seed is continuing into the fourth year. The object here is to examine the influence on seed longevity of storage atmosphere (hermetic seal, vacuum seal and CO_2 gas seal), seed moisture content (4 to 16%) and storage temperature (–20°C to +20°C). The results will be analysed in 1964 after 5 years storage. Germination tests are being carried out after 1, 2, 3, 5 and 10 years storage.

NURSERY INVESTIGATIONS

By J. R. ALDHOUS and J. ATTERSON

The programme of experimentation in nursery nutrition carried out jointly with the Rothamsted Experimental Station continues. Progress reports are temporarily suspended to allow Miss Benzian of Rothamsted to complete the publication of the experimental work between 1945 and 1962. The first volume of this publication, is now in the press.

Factors Influencing the Yield of Seedlings

Irrigation, Date of Sowing and Seed Storage

The response of stored seed to date of sowing (and, at Kennington only, to irrigation), was tested for the second year at Wareham, Dorset; Bramshill, Hants; and Kennington, near Oxford. Seed of Sitka spruce, Western hemlock, and Japanese larch was sown. There were three lots of seed of each species; two lots differed by one year in age, while the third lot was the same age as one of the others, but of a different provenance. Seed was sown at approximately fourteen days intervals between early March and mid-May.

The sowings made before mid-April gave high yields of well-grown seedlings; the numbers and heights of seedlings from later sowings were less than from the early sowings, especially with the mid-May sowing, which was almost a failure. At Kennington the application of water by over-head spray line increased yields from the later sowings but had little effect on early sowings. The age of seed or period of storage had little effect on yield or growth. There was no difference between provenances of Sitka spruce and Japanese larch, but Western hemlock seedlings raised from seed from Washington, U.S.A., were taller by the end of the growing season than seedlings of more northerly origin, but suffered more from autumn frosts.

This experiment is planned to be repeated for a third year.

Irrigation

A large-scale irrigation experiment was continued for a second year in Wigtownshire, at Bareagle nursery. This Conservancy nursery lies in an area receiving 38 in. rainfall per annum, has high sunshine figures, a very light soil, and an exposed situation. In 1962, the weather there was cool and wet, and perhaps for this reason no significant differences were found in numbers, mean height, root weight, top weight, or root weight/top weight ratio between irrigated and non-irrigated plots of one-year-old seedlings of Sitka spruce, Lodgepole pine, and Japanese larch.

The Influence of Seed Size on Growth of Plants

A small sample of Scots pine seed was supplied by Capt. Brander-Dunbar from trees at Pitgaveny, Moray, where selection for seed size has been carried out over a long period. The sample was graded by sieving into three lots and sown in pans in early June. The resulting seedlings, which were smaller than normal (due to late sowing), were lined out at Kennington in spring, 1962.

Table 3 gives the size of seed and seedlings.

TABLE 3

SIZE OF PLANTS GROWN FROM GRADED SEED

Seed Lot	Seed Size	% Survival as 1 Year Seedlings	Height in Inches		Stem Diam. in mm.	
			1 yr. Seedlings	1+1 T'pl.	1 yr. Seedlings	1+1 T'pl.
A	Passed 2.057 mm. mesh sieve	76	1.6	3.0	1.2	3.9
B	Retained on 2.057 mm. mesh sieve. Passed 2.411 mm. mesh sieve	61	1.8	3.1	1.3	4.0
C	Retained on 2.411 mm. mesh sieve	66	2.1	3.9	1.4	4.6
	Standard error		0.15	0.17		0.10

Both the height and stem diameter of transplants raised from the largest grade of seed were significantly greater two years after sowing than those from small seed.

Nutrition of Nursery Plants

Long-term Maintenance of Fertility

At Teindland Heathland Nursery, Moray, the long-term fertility maintenance experiment comparing organic and inorganic regimes was continued for its thirteenth year. Both the height growth and out-turn of seedlings were less than in any previous year, due to a combination of late sowing (15th May) and the cold wet season. Nevertheless, on the organically manured (hopwaste) plots the height growth and colour of both Sitka spruce and Lodgepole pine were superior to that on the fertilizer plots, but the stocking of Sitka spruce seedlings was, as usual, lower on the hopwaste plots. During the thirteen years of this experiment, the seedbeds have received a total cover of 2½ to 3 in. of grit, and this is now very obvious on those plots which have *not* received hopwaste.

The similar experiment at Bramshill was closed at the end of the year under review, its thirteenth growing season. The final results of plant production and soil analysis, will be given later when analysis is complete.

New Fertilizer Formulations

On Sitka spruce seedbeds at Bush Nursery, several new forms of inorganic fertilizer were compared with the normal fertilizer treatment consisting of application of potassic superphosphate before sowing, followed by a top-dressing of 'Nitrochalk' in the middle of the growing season. These new forms are pelleted compound inorganic fertilizers with an N:P:K ratio of approximately 2:1:2, with water-resistant coatings. Such coated fertilizers might permit the application of nitrogen to the seedbed prior to sowing, without the hazards associated with this practice.

Six different formulations were tested. All produced slightly (but not significantly) taller seedlings than those grown by the normal fertilizer regime. Surprisingly, numbers of seedlings were lower with all coated fertilizers, although again not significantly. At the end of the growing season, the normally manured plants were greener than any of those on the other treated plots, but during the winter the differences disappeared. The indications are promising enough to warrant further trials.

Protection

Protection Against Birds

Thiram, polythene sheet and netting were tested as means of reducing bird damage to Scots, Corsican and Lodgepole pine and Sitka spruce seedbeds at Wareham (Dorset) and Bramshill (Hants).

Thiram (tetramethyl thiuram disulphide), formulated as a seed dressing (50 per cent active) and a wettable powder (80 per cent active), was applied as a seed dressing, using a bitumen sticker. Both materials were applied at the rates of 5 per cent, and of 10 per cent, by weight of formulation per unit weight of seed.

Clear polythene sheet was laid across the bed and fastened down at the edges to prevent it blowing away. The sheeting was left in position until first emergence of seed was observed three or six weeks later respectively. Wire netting was arranged over certain plots to prohibit entry of birds.

There were also the following treatments:

No protection
Seed coated with bitumen sticker only
Seed coated with bitumen and then dusted with aluminium powder
Seedbeds sprayed once a fortnight with aldrin.

Unfortunately neither experiment was subjected to much bird damage, though birds had been active in the same areas in previous years, and no conclusion could be drawn about the effectiveness of any of these measures to protect seed and seedlings from birds. However, useful information was obtained on the hazards of certain of the protective treatments.

At Bramshill, on all plots where bitumen had been used as a sticker, the yield of seedlings was lower than on control plots. No effect was attributable to the rate or formulation of thiram used. The yield of seedlings was also reduced on plots covered with polythene sheeting. The longer this was kept in position the greater was the reduction in number; but on the plots covered longest, the surviving seedlings were biggest.

At Wareham, the bitumen sticker also reduced the yield of all species. Thiram wettable powder at the higher rate significantly reduced the number of Scots pine seedlings at the end of the season: otherwise there was no effect attributable to the rate or formulation of thiram. Polythene sheeting had no effect on seedling numbers at Wareham, but Sitka spruce and Corsican pine seedlings on plots covered until six weeks after germination were significantly the tallest in the experiment.

Two further experiments were laid out under the direction of Miss J. J. Rowe. At Bramshill, bitumen and latex were sprayed onto the surface of the soil to protect Corsican or Scots pine seed against bird damage. The bitumen was formulated as a 40 per cent emulsion; the latex was a butadiene copolymer containing 47.5 per cent solids. Both materials were sprayed at the rate of 75 millilitres per square foot. Other plots were covered with grit (standard practice-control), polythene alone, or grit and polythene. Seed was sown in mid-May (i.e. very late) onto rather dry soil.

Both the latex and the bitumen prevented virtually all germination of either species. Germination under the polythene sheet was good, but radicles of seedlings on plots covered with polythene alone appeared unable to penetrate the dry soil and by mid-July most of these seedlings had died. Seedlings on the plots covered with grit and polythene together rooted normally, but were significantly fewer than on the control plots.

In another experiment, sowings of Corsican pine covered with grit, following standard practice, were protected either with polythene sheet, $\frac{3}{4}$ inch mesh wire netting or "Scaraweb". The polythene protected plots were covered by a tube laid flat, with wires under tension inside the tube at the edges and pinned down. "Scaraweb" is supplied as a cord made up of approximately 47,000 fine rayon strands. The cord can be spread out at right angles to its length to give a fine web up to 75 feet wide. The web breaks up after a few weeks. None of these measures had any significant effect on the number of seedlings germinating. "Scaraweb", when spread flat on the bed, did not appear to deter birds from settling to pick up a seed, but bird attack was insufficient to provide a quantitative test.

In a supplementary trial sown in mid-May, three or four weeks after the main sowing, the same treatments were applied. The polythene sheet drastically reduced the number of seedlings compared with "Scaraweb" or netting. Again, the soil was dry and seedbeds prepared late.

The conclusions to be drawn from recent work on protection against birds are:—

(i) Bitumen is not a suitable sticker for repellents.

(ii) No evidence was forthcoming about the effect of thiram as a bird deterrent, but there was a slight indication that, at high rates and formulated as a wettable powder, it is toxic to pine seedlings.

(iii) Polythene sheeting can be used as a physical barrier over seedbeds, but if it is not to reduce yields the soil must be moist when seed is sown; also, the sheeting must be removed within two or three weeks of germination. It can be fixed over seedbeds but this is a slow tedious operation; also, it has to be removed before any pre-emergence sprays can be applied to control weeds, whereas with wire netting, sprays can if necessary be applied through the netting. For these reasons it is unlikely to be any cheaper to use in practice than netting, and in some respects, it is more hazardous.

Control of Weeds

Effect of Soil Reaction (pH) on Weed Growth

At Kennington and Wareham, the effect of soil reaction (pH) on growth of conifer seedlings has been demonstrated over many seasons in experiments designed to display a range of reactions. Weed growth has also been seen to be influenced by reaction. This effect was studied at both nurseries by recording the time taken to remove weeds by hand and by assessing the number and fresh weight of each species of weed present. The dominant weed in both experiments was *Poa annua;* the response to soil reaction of this weed ran parallel with that of conifers such as Sitka spruce, and optimal growth was found at pH 5.5. A fuller account of these experiments will be given elsewhere.

Pre-emergence Weed Control in Seedbeds

Paraquat and amiben were sprayed onto seedbeds at Kennington, seven, and fourteen, days after sowing, and at the time a conventional pre-emergence oil spray would be applied. Paraquat* was sprayed at 1, 2 and 4 lbs per acre and amiben at 2, 4 and 8 lbs per acre. Amiben caused heavy losses to all four species sown (Japanese larch, Sitka spruce, Douglas fir, and Lodgepole pine) no matter when applied or at what rate. This was in contrast to the previous year's results when amiben did practically no damage. Paraquat did no damage to any species. The time taken to hand-weed plots sprayed with paraquat was on average higher than for vaporising oil, but this appeared to be due to unexpectedly large populations of weeds on one replication of each paraquat treatment. The rate of application of paraquat had no effect on the control of weeds achieved. The soil at Kennington is a light loam.

Post-emergence Weed Control

Two residual weedkillers, Neburon and Diuron, were sprayed on seedbeds sown with Sitka spruce, Japanese larch, Scots pine and Western hemlock. Neburon was sprayed at 1, 2 and 4 lbs. per acre (active ingredient) using a 50 per cent wettable powder; diuron was sprayed at ½, 1 and 2 lbs. (active) per acre using an eighty per cent wettable powder. Each material was applied in forty gallons of water per acre, four or seven weeks after germination was first observed.

Diuron reduced crop yields whenever applied; but neburon had no significant effect on the crop. The weeding times on the neburon-treated plots were reduced by between sixty and eighty per cent.

The two higher rates of application of neburon were equally good and both were appreciably or significantly better than the 1 lb. per acre rate.

This is one of the most promising results yet achieved with a residual post-emergence weedkiller on conifer seedbeds.

Pre-sowing and Pre-transplanting Control of Weeds

Dichlobenil (2, 6-DBN*) was applied two, three and four months before sowing seed or transplanting and seedlings of Sitka spruce, Douglas fir, Japanese larch and Lodgepole pine. A wettable powder formulation of dichlobenil was applied at ½, 1 and 2 lbs (active) in forty gallons of water per acre and was cultivated into the top three inches of soil immediately. Yield and growth of both seedlings and transplants of all four species were reduced by all treatments whatever the interval between application and cropping. This was the third year dichlobenil has been under trial. The first year's results indicated that this material might be useful in forest nurseries (Aldhous 1960) but in both subsequent years, it has appeared to be excessively persistent and has caused crop damage when applied at rates of ½ lb. per acre or more.

Weed Control in Transplant Lines

Simazine is now used extensively in forest nurseries to control weeds among transplants. In experiments to study the effect of repeated applications, simazine will be applied annually to the same plots at Kennington and Wareham at up to eight lbs (active) per acre. The normal rate of application is 2 lbs (active) i.e. 4 lbs of fifty percent wettable powder. In the year under review (the first year of these experiments), plots were lined out with European and Hybrid larch,

* For details of full chemical names and properties of paraquat and amiben and other chemicals mentioned here, see *Weed Control Handbook*, Ed. Woodford 3rd Edn., Blackwell, Oxford.

Picea omorika, birch, alder, lime, sycamore, *Nothofagus* and Western hemlock. No species was affected by any rate of simazine at either nursery. The absence of damage to European larch and *Picea omorica* (which has previously appeared susceptible) on plots treated at high rates was attributed to the fact that both experiments were lined out towards the end of April, and the weather subsequently was dry and cool, thus minimising the downward movement of simazine in the soil.

Other Residual Weedkillers in Transplant Lines

Seven herbicides which might be used among transplants in place of simazine were screened at Kennington and Wareham for phytotoxicity to Sitka and Norway spruces, Scots and Lodgepole pines, European and Hybrid larches, Douglas fir, Western hemlock and Western red cedar, Lawson cypress and oak. Prometryne, atrazine, propazine, and diuron were each supplied at 1, 2 and 4 lbs. (active) per acre, amiben and neburon at 2, 4 and 8 lbs (active) and dichlobenil at ½, 1 and 2 lbs (active) per acre. All but the dichlobenil were sprayed as wettable powders in sixty gallons of water per acre. Dichlobenil was spread in granules containing 3.5 per cent active ingredient; these were hoed into the top one inch of soil immediately after spreading.

There was no significant reduction in height or survival of any species, but slight damage was observed on plots treated with the highest rate of amiben and diuron. Best control of weeds was obtained with atrazine, propazine and diuron, significantly better control being obtained with each material on the plots treated at the highest rate.

Phytotoxicity Test

The phytotoxicity of paraquat to a range of forest species was tested at Kennington. Paraquat was applied as an overall spray in late May to Sitka spruce, Scots, Lodgepole and Corsican pines, Lawson cypress, Western hemlock, Japanese larch, Douglas fir, ash and sycamore. Rates of application were ¼, ½, 1 and 2 lbs (active) in forty gallons of water per acre. All species sustained severe damage and all the conifer species except Corsican pine were killed by the heaviest rate. Survival of the two hardwood species was not affected and plants sprayed with paraquat at 1 lb (active) or less, though completely defoliated by the spray, recovered and made normal growth.

Handling and Storage

The Transport of Plants

Losses are sometimes sustained through polythene bags of plants being left exposed to sun. Several types of bag considered less likely to 'heat up' when exposed at the planting site were tested at Kennington. The bags were made of either metalised terylene sheeting (Melinex), or 2-ply Kraft paper, the outer ply being made of a paper with a high wet-strength and the inner ply coated with polythene. Clear and tinted polythene bags were used as controls.

The bags were filled with plants and were laid out fully exposed to the sun for approximately three weeks. The temperature inside the bags was recorded by thermograph. Plants inside the metalised terylene bags kept cool and stored well; by the end of the period however, the bags themselves had lost part of the metalising where plants had rested. Plants in the paper bags stored quite well, but the bags rotted where in contact with the ground so that the wet-strength was lost. In the clear and in the tinted bags of polythene, the plants on the side exposed to sunlight were very severely damaged and some were killed outright.

Cold Storage of Plants

Trials were continued assessing the practicability of cold storage of plants, both to facilitate transplanting late in the season, and to enable surpluses to be held over and utilised. A full account of this work has been accepted for publication (Aldhous 1964).

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ALDHOUS, J. R. 1960. A Preliminary Experiment on 2,6–dichlorobenzonitrile. *Proc. 5th Brit. Weed Control Conf.* 617–622.

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SILVICULTURAL INVESTIGATIONS IN THE FOREST

By M. V. EDWARDS, R. M. G. SEMPLE AND SILVICULTURE STAFF

The report is in much the same form as last year's. The projects directed by G. D. Holmes, who left Research for the North Wales Conservancy towards the end of the year under review, are mentioned in less detail than previously, since it has been necessary to re-allocate and at the same time review the work concerned. The authorship of each section is shown by initials, which are explained at the end of the chapter.

AFFORESTATION OF DIFFICULT SITES

The Northern Isles

Periodic inspection of the experimental plantings has continued and the preliminary results will shortly be published.

Occasional mention of this work in the Shetland Press has led to frequent enquiries by private persons wishing to plant trees for shelter around their houses. Where possible, advice is given on the spot by Research staff when visiting the islands, and a record of these tree-planting attempts is being kept.

S.A.N.

Plantations at High Elevations

Advisory work and recording of establishment work continues. It is planned in the coming year to summarise the early progress of all plantations in this project which are over six years of age.

S.A.N.

Upland Heaths – Cultivation

Interest here centres on the size of the benefits provided by deep (12 to 16 inches) complete ploughing compared with single line ploughing at intervals (spaced furrow ploughing) in view of the higher cost of the former. Three experiments have treatment plots large enough to give long-term results on volume production; the recent establishment of the one at Inshriach was described in the *Research Report* for 1962. That at Teindland, Moray, has had its ten-year assessment and the one at Harwood Dale, Yorkshire, its six-year assessment. In the former, on a very compact, stony soil, the treatments involving complete surface cultivation, both deep and shallow, have given 22 per cent greater height growth of Scots pine, Lodgepole pine and Japanese larch than those involving spaced furrow ploughing. The improved growth is also related to the volume of soil disturbed in ploughing. At Harwood Dale, on a rather clayey soil, the best growth has followed treatments involving the deep excavation and turning of the soil. These cultivations were effected by the 'R.L.R.' plough, and it seems probable that the action of this plough favours the drying and weathering of the heavy clods from the deeper soil levels, with consequently improved root development. Growth at Harwood Dale is not so closely related as at Teindland to the volume of disturbed soil, though the complete ploughing with the R.L.R. plough is better than the spaced furrow work with this plough.

Upland Heaths – Manuring

The growth after canopy closure of Sitka spruce at Wykeham (Yorkshire upland heath) has been generally disappointing. It has usually been assumed that the suppression of *Calluna* would represent a critical stage, but several crops which as a result of intensive early treatments have succeeded in this, have still not grown satisfactorily. It is now believed that inadequate moisture (in the soil or atmosphere) may be the main limiting factor. It is proposed to apply the optimum rates and balance of nutrients based on foliage analysis. This 'all-or-nothing' approach is also being used on a stagnating larch crop at the Dalby section of Allerston. If a worthwhile response is achieved, subsequent experiment can isolate the effective nutrient. Failing responses, it can be assumed that the trouble is not nutritional.

S.A.N.

AMELIORATION OF FOREST SITES

Drainage

General

During the year the whole subject of forest drainage has been reviewed jointly by several sections of Research Branch, principally Silviculture and Soils. The results of the study will be circulated, initially within the Commission, as a guide to the basic principles underlying the drainage of the soils most used for forestry and to the practical application of these principles. The main thesis is that forest drains should be considerably deeper than has been usual during the period of post-war expansion, and that attention should be paid to the alignment of the drains so as to obtain the greatest interception possible while providing some fall in the drains. The need is indicated for special equipment where such drains cannot be formed with ploughs (much the cheapest method), and the value of tractor-mounted, hydraulically-operated diggers is emphasised in this respect. The increase in drainage expenditure implied by these recommendations is recognised, but this must be set against the benefits of increased stability and longer rotation, perhaps with greater increment, which may be found in succeeding rotations.

A.I.F. and D.W.H.

Deep Peat

Preparations have continued for the large-scale experiment in the drainage of a deep raised bog at Flanders Moss, Loch Ard Forest. Drain spacings of 25, 50 and 100 feet will be compared, each at depths of 2 feet and 4 feet, between which the ground will be turfed by normal double-mouldboard ploughing. In addition, the current practice of 5-foot spaced single-mouldboard ploughing will be compared, and the experiment will include the use of subterranean drains similar to the mole-drains of agricultural practice.

The effects of water-logging on soil aeration and growth of potted tree seedlings have been under examination by the Forest Soils section of the Macaulay Institute for Soil Research, and this year part of this work has been extended to the forest. On the Lon Mor experimental area, Inchnacardoch Forest, Inverness-shire, a poor peat soil will be subjected to varying levels of moisture by maintaining water-filled ditches round the plots. Soil temperature, oxygen concentrations and ground-water levels will be studied in relation to the growth and health of Lodgepole pine in the plots.

D.W.H.

Mineral Soils

The experiment at Lennox Forest, Stirlingshire, described in the *Research Report* for 1961, page 35, has now provided a year's data on the movement of water levels in test-wells. The general level of standing water during 1962 was very near the surface—about five inches below ground level after a rainy spell and about ten inches below after a prolonged dry spell. A capillary fringe of water-logged soil standing above these levels probably extends to the surface for much of the year, and must play a large part in the poor root development and health of Sitka spruce in the forest. The general water level was about one inch deeper during May-July than in the spring and autumn. Draining to two feet deep at ½ chain intervals has lowered the level of water in bore holes between the drains by about 1½ inches during the first year after the drains were dug, this difference being established within three months of draining. The effect is a small one, and confined so far to the soil horizon in which moisture movement is fairly free in any case, i.e. the upper nine inches of loamy topsoil. Improvements in water movement at depths of 18–24 inches will probably take much longer to develop.

The large experiment at Halwill (Devon), designed to examine the effect of deep (30 inch) drains at a range of spacings on the growth and rooting of Sitka spruce on a heavy clay soil, has been laid down and planted. Additional treatments are mole ploughing and admixture of Red alder as methods of encouraging deep rooting of Sitka spruce on this difficult site. Flow-meters and bore-holes have been established by the Soils section and already big differences in the bore-hole levels have been recorded compared with the previous year, before draining.

A site has been selected and surveyed at Orlestone (Kent) for another large drainage experiment, intended to examine the effect of three drain depths and drain spacings on the water level in the soil and on the subsequent root development of several species of tree.

In connection with the review of drainage practice mentioned above, a demonstration area comprising five compartments of the Mounces Beat of Kielder Forest, Northumberland, was established on which to implement the recommendations of the review. The variety of drain alignment, spacing and gradient represented in this area, within the limits of the recommendations, will provide the basis for later studies of drain performance, erosion, maintenance costs, etc.

Research Branch has co-operated with several Conservancies in demonstrations of a hydraulic excavator on site-types ranging from deep peat to heavy clay. In stump-covered ground such machines should be mounted on wheeled tractors; on previously unplanted land, drains should be formed by plough whenever the required depth can be attained in this way, as costs are much lower even where two tractors are required to haul the plough.

D.W.H. and A.I.F.

Manuring

General

In Wales and Southern England no major experiments were started; assessment and observation of existing experiments progressed satisfactorily, and a large volume of data is now to hand and in process of being analysed. Future work in this field will be the province of the Soils section at Alice Holt so far as the South of England and Wales are concerned.

A survey in questionnaire form was made of the use of artificial fertilizers in Forestry Commission forests during the Forest Years 59, 60 and 61. Conservancy offices were asked to state the total amount of fertilizers applied in each year, distinguishing between:

(a) fertilizers applied to newly planted crops (i.e. within three years of planting) and to older crops.

(b) Ground mineral phosphate, basic slag, superphosphate, triple superphosphate and other fertilizers.

An analysis of the information indicated:

(a) that the use of fertilizers had increased steadily over the three years.

(b) the greater part of the fertilizer used was applied within three years of planting.

(c) ground mineral phosphate is used in much greater quantities than any other fertilizer; triple superphosphate came next, but was far behind the G.M.P.

(d) in general the results achieved by the use of fertilizers were distinctly satisfactory.

These indications were relatively clear cut, and were, indeed, expected. What was, perhaps surprising was the wide variation in practice within the Commission in the use of fertilizers. This variation was very marked between Conservancies but was detectable *within* them as well. Quantities used, type of fertilizer, application rates and techniques and the reasons for application, all showed large differences, not readily explicable in the light of differences of site and planting programme. There is clearly matter for further study here, both by Research and Conservancy staff.

R.M.G.S.

Peat

A joint experiment with the Nature Conservancy has been established at Slattadale on the lower slopes of Beinn Eighe in Wester Ross, to investigate the long term effect of manuring on blanket peat which in that area varies in depth from twelve inches on knolls to more than six feet in hollows. The species planted are Scots pine (ex Loch Maree) and Common alder (*Alnus glutinosa*). The Nature Conservancy will be following the changes taking place in the soil and the Forestry Commission will assess the effect of various levels of manuring on the tree growth.

A large experiment was established last year at Arecleoch in Ayrshire to compare (a) the mechanical application of ground mineral phosphate while ploughing with (b) hand application after planting, and the interaction of these two methods with position of planting. Unfortunately, this experiment has suffered severe losses during this past winter, especially where planting was on the ridge top (survival 45 per cent). Where planting was on the side of the ridge (the step or 'wedge' method), survival was 82 per cent. No differences in survival due to the method of application of the ground mineral phosphate, were shown.

Checked Plantations

Several hundred acres of the Achray section of Loch Ard Forest in Stirlingshire, planted with Sitka spruce, have gone into "check". Chemical analysis of the foliage has indicated that the checked trees have low foliage levels of phosphorus and potassium. These nutrients will be applied by aircraft; it is intended to follow growth responses by foliage analysis and by measurement of height.

The Conservancy manuring experiment at Laurieston Forest in Kirkcudbrightshire (reported in the *Report on Forest Research*, 1961, p.36) on Lodgepole pine and Sitka spruce has been assessed yearly since its establishment in 1960. The compound fertilizer containing N, P, and K continues to improve the height of both species, when compared with trees given ground mineral phosphate or with the controls which received nothing. (See Table 4).

Table 4

PERCENTAGE INCREASE IN HEIGHT, OVER HEIGHT AT THE END OF 1959, THAT IS, HEIGHT BEFORE THE FERTILIZERS WERE APPLIED

Species	Time of Assessment end of:	Treatment		
		Compound NPK Fertilizer	Ground Mineral Phosphate	Control—No Fertilizer
Sitka spruce	1960	50	24	33
	1961	105	43	53
	1962	144	62	64
Lodgepole pine	1960	44	39	40
	1961	101	68	66
	1962	154	86	90

Note: General mean height at end of 1962 for all treatments was 4½ feet.

A later application of di-ammonium phosphate has indicated that the application of N + P on this deep peat site does not result in as good a response in height growth as an application of N + P + K.

Pole-stage Stands

Band-dendrometer data from the large-scale 3^5 factorial experiment comparing three levels of N, P, K, Ca, and Mg on 35 foot high Norway spruce at Durris Forest in Aberdeenshire have been analysed and show significant responses in girth only to the application of potassium.

J.A.

ARTIFICIAL REGENERATION

Spruce

Size of Felling Area

The major experiment at the Forest of Ae (Dumfriesshire) which compares the windthrow resulting from four sizes of felling area, has now been subject to the gales of one year. A total of approximately 2,000 trees have been windthrown or broken on the one-chain (66 feet) wide assessment zone which surrounds each clearing. The relative importance of the various factors involved (i.e. size of clearing, peat depth, tree height, wind direction and force) have not yet been analysed, but it appears at this stage that the largest clearing (ten acres) has resulted in the lowest amount of windthrow *per acre felled*, as shown in Table 5. The significance of this result is under investigation.

Table 5

NUMBER OF TREES DAMAGED IN FELLING AREAS OF DIFFERENT SIZES

Size of Felling Area (acres)	Total Length of Original Perimeter (Chains)	Total No. of Trees Blown/Broken March, 1963	No. of Trees Blown/Broken per Chain of Perimeter	No. of Trees Blown/Broken per acre felled
10.0 (1 plot)	40.0	1,085	27	108
1.0 (3 plots)	37.0	400	11	133
0.3 (3 plots)	19.5	146	7	146
0.1 (10 plots)	38.0	366	10	366

The first year survival of Norway and Sitka spruce, the two main species used to replant these clearings, was generally good in spite of the late planting which was followed by an extended dry period. It was noted that the planting turfs in the smaller clearings retained their shape, weight and moisture better than those in the centre of the ten-acre clearing and this was reflected in a significantly better plant survival.

Restriction of Windthrow

The instability of the margins of clear-felled or wind-thrown groups (or roadline fellings) is a nuisance to forest management, and is frequently given as a reason for not replanting recently wind-thrown areas where fencing is essential. An inconclusive attempt to stop the spread of wind-throw by topping trees on the margin was carried out at Newcastleton (Roxburghshire) and at Benmore (Argyll). This year more critical comparisons of various treatments to promote tree stability have been established on various sites, mainly in the Border forests. Treatments include topping of trees, ultra-high pruning, killing by application of ammonium sulphamate, and the removal of dominants and co-dominants. Treatments are paired with untreated controls, and it is hoped that this will provide preliminary indications of the most promising type of treatment which can thereafter be studied more critically.

Survey of Windthrow

Since 1958 windthrow of Sitka spruce has increased considerably at Kershope Forest (Cumberland). An extensive survey of windthrown areas has been planned in order to clarify the influence of topography, soil and crop on the occurrence of damage.

S.A.N.

Japanese Larch

The three experimental sites mentioned last year (Drumtochty, Kincardineshire; Radnor, Radnorshire; Coed Morgannwg, Glamorgan), were laid out and marked for thinning in October 1962. Owing to the severe winter, felling was not started at Radnor, but the other two sites were planted by the end of the year under review, although refrigerated plants had to be used to extend the planting season at Drumtochty.

The experiment is designed to study the effect of various densities of Japanese larch overwood, on the growth of the overwood itself, and a range of underplanted species. The treatments, five in number, range from clear felling the larch to thinning it to a stocking of 200 stems per acre, and under-planting with seven different species. In each case there is an eighth unplanted plot except in the clear-felled treatment where this is used for replanting Japanese larch. In addition there are plots in which the Japanese larch had been, and will continue to be given, a normal "moderately heavy" thinning.

A.I.F. and S.A.N.

General

Survey of the Fort William Pulpwood Area

The new pulp mill under construction at Fort William, on the west coast of Inverness-shire, will entail clear felling to obtain adequate supplies in the initial years before normal thinning yields produce the bulk of its intake. Research Branch began to establish experiments on various regeneration problems in 1958 and the majority of these are situated in the Border region. This year a preliminary survey in North and West Scotland was completed to determine what new silvicultural problems are posed by the pulp mill development, and to what extent research work done to date is relevant to them.

In North Scotland proposals for the felling of mature Scots pine and unsatisfactory larch crops pose many managerial and organisational problems. Silviculturally the problems do not appear to be so great. The felling and replacement of Scots pine is a familiar operation, and the larch (to be replaced largely by spruces) is situated mainly in the relatively open-textured soils on steep slopes with irregular topography and stocking where it is unusual to find large blocks without a change in aspect, height class or species. Hence a major threat of windthrow, though the need for expensive drainage does not seem to be nearly as great here as in the Borders. Thus experimental work has been concentrated where adverse conditions are most extreme and where ground conditions are more regular, making experimentation simpler and the results more widely applicable.

In West Scotland, in addition to unsatisfactory larch crops, much of the early felling will be in deer-damaged Norway spruce, wind-damaged crops (mainly spruce) and spruce crops more economically felled than thinned. This preponderance of spruce felling, much on steep slopes in high rainfall areas, raises two new problems. Firstly the theoretical risk of sheet erosion leading to the loss of valuable top-soil, and secondly the cheapest means of dealing with the lop and top. Mechanical chopping of this material (see below) will be impossible on most of the ground which is too steep or rocky for a tractor to operate.

Because of the current marketing difficulties in these areas, and the need to conserve material for the pulp mill, it is not proposed to intensify regeneration research in this area until the onset of felling. It is probable that research will then be expanded on the lines of the work undertaken in the Borders.

Disposal of Lop and Top

Trials of the Wilder Rainthorpe chopper were carried out on turf-planted clear-felled Sitka spruce at the Forest of Ae (Dumfriesshire), and at Hamsterley Forest (Yorkshire) and on clear-felled Scots pine at Kemnay Forest (Aberdeenshire) and at Thetford Chase (Norfolk). These trials confirmed the promising capabilities of this machine, a more robust version of which has now been built. On turf-planted areas a crawler tractor was found unsuitable as it frequently shed its tracks, but a 4-wheel-drive Fordson Super 4 tractor proved considerably better and reduced lop and top to coarse mulch through which notch planting was simple. The cost of chopping was considerably less than the traditional heaping and burning of brash.

A.I.F. and S.A.N.

Manuring – Second Rotation Crops

The ploughing experiments on clay at Lennox Forest (Stirlingshire), and on upland heath on the Dalby section of Allerston Forest, which were described in the *Research Report* for 1960, each included the normal rate of ground mineral phosphate as an experimental treatment. The third-year survival and height assessments show no response to the phosphate application. This absence of worthwhile response is not surprising as it is known that the previous crops on both sites grew satisfactorily in their early stages until vigour fell off in the early crop phase.

However, it has been noted here, and frequently elsewhere, that trees replanted immediately after clearfelling do not grow quickly in the first two years and hence fail to utilize the weed-free conditions that exist for this short period. As a result these trees may have to be weeded two or three times before successful establishment. It is believed that this temporary but costly check may be due to nitrogen deficiency and this year an initial nitrogen application in the form of "Nitrochalk" at two rates is being tried on several species (Norway spruce, Sitka spruce, Western hemlock, Silver fir and *Abies grandis*), at several forests, on direct notch- and turf-planted trees. Nitrogenous fertilization, though frequently effective, is not generally used because its effects are short-lasting, but in this project only a short term boost is required and if thereby one or more weedings can be avoided the procedure would be of value.

S.A.N.

NATURAL REGENERATION

A seed trap has now been designed which fulfils the requirements of all those concerned in collecting seed. A number of these were built early in the year, and they have been found satisfactory.

An investigation was carried out in conjunction with the Entomology section in a Douglas fir seed stand in the New Forest. Seed counts were made at intervals throughout the winter and spring, and the results showed a moderately high seedfall. The Entomologist is assessing the proportion of seed infested with the Douglas fir seed fly, *Megastigmus spermotrophus*, so that it will be possible to get an idea of the number of potentially viable seed.

This project will be continued and extended to other stands in order to study the seasonal and geographical variation in seedfall.

A.I.F.

SPECIES TRIALS AND ARBORETA

Leyland Cypress

Two small further trials of Leyland cypress, *Cupresso-cyparis leylandii* have been made on a heath site (after a larch pioneer crop at Allerston), and on deep peat in Caithness. The earliest results from some thirteen small plots on a range of sites have not been as promising as in the South-West of England and Wales.

No new plots were laid out in Wales or the South of England, but propagation work is in hand with a view to extending the present representation.

A study of the written history of the propagation of Leyland cypress and the herbarium specimens at Kew, confirm the results from comparisons of the foliage of clones being propagated, with foliage from the original parent trees. The clones are now identifiable and the original trees from which they arose are known. The distinctions among the clones now in use, and the other parent trees, and the full results of the study, are being published elsewhere.

S.A.N. and A.F.M.

Swedish Birch

A trial of Swedish birch has been planted in comparison with Scottish birch at Ceannacroc (Inverness-shire) with the object of comparing quality on a good site. In the past Scandinavian birch has occasionally been used but being sited on rather infertile sites it has always failed to grow satisfactorily.

Sycamore

It frequently happens, particularly on acid grasslands, that sycamore checks for a long period after planting. Various measures (e.g. mulching, slow-acting nitrogen fertilizer, and cutting back) have been unsuccessful in accelerating establishment. A combined 'luxury' treatment is now being attempted. If successful, the treatment might be refined—if not, the project will be abandoned. One motive for the experiment is to obtain a guaranteed procedure for use in the far North where sycamore is much appreciated for shelter for gardens and farm steadings.

S.A.N.

Nothofagus

Although in our trial plots the early growth of both *N. procera* and *N. obliqua* has been most encouraging on good sites, the incidence of stem cankers and lesions (especially on *Nothofagus procera*) often accompanied by severe crown die-back, has been a most disturbing feature.

At the moment it is not possible to say with any certainty what factors are causing the die-back, although rapid growth and periods of very low temperature may well be the most dangerous combination of circumstances. Most of the examples have occurred in recent years, and over a wide range of sites; by no means every stand has been affected but the incidence of the trouble is sufficiently frequent to merit serious investigation and to advise extreme caution in the use of both species at present.

M.N.

PROVENANCE

Scots Pine

The three experiments planted on Mull and on each side of Loch Fyne, (Argyll) were assessed for height, survival, needle retention and climatic needle browning at ten years of age. The "control" experiment in an inland area at Torrie Forest (Perthshire) was also assessed. The west coast sites showed a similar pattern of growth and resistance to winter blasting. Asknish experiment showed the fastest growth and the better plots have closed canopy; Strathlachlan was next best for height growth and it showed less blasting than the Mull experiment, in which nearly every tree had brown foliage. The outstanding exception was a provenance from Hedmark in east Norway which was highly resistant to winter blasting at all three sites, though its rate of growth was poor. The Scottish west coast provenances from the Isle of Raasay, Baranlongart Estate and Carradale forest in Kintyre were generally more resistant to climatic needle browning than those from east Scotland, though a provenance from Altyre Estate (Morayshire) made good height growth despite its brown needles A provenance from Thetford (Norfolk) was outstandingly tall at the inland Torrie site, but was surpassed by the Scottish origins at the west coast sites. Two west Norwegian provenances from Svanoy and Sogndal, performed very badly on the coastal sites, both in resistance to climatic damage and in height growth. At Torrie they were relatively less poor; as no needle browning occurred there the Hedmark provenance was inferior to the Scottish provenances.

The rust fungus *Peridermium pini* has caused a number of deaths in the provenance experiment at Teindland (Morayshire) planted in 1928. Three Finnish provenances from Ahtari, Viborg and Kittila were heavily affected, while one from Hagenau in Alsace was lightly affected. The Finnish provenances have grown slowly. Scottish provenances from Beaufort and Pitgaveny have grown fast and were little affected by *Peridermium*, but one from Loch Maree which is also fast-growing was badly affected by the rust.

Pinus nigra

A new seed collection of provenances from selected stands in Denmark and from smoke-polluted stands in the Pennines was sown at Delamere heathland nursery.

Twenty-two provenances of *P. nigra* from Central Europe and two from plantations in England have been sown at Wareham research nursery. The majority of these provenances were from calcareous sites and the remainder from vigorous stands on non-calcareous sites. All of them, it is hoped, will be planted on shallow sands over chalky boulder clay in East Anglia and on shallow soils over limestone elsewhere.

The experiments planted in 1960 at Stenton, East Lothian, and South Yorkshire Forest had very good survival after three years and did not differ significantly. There was a great variation in the height growth of seed lots from various places in Europe, but of common Calabrian origin. The tallest provenance at both sites was from the Arboretum of Les Barres, France. The next tallest was from the Forêt de Koekelare in Belgium. The poorest growth was made by provenances imported *directly* from Calabria (Mt. Sila) and from the Abruzzi of central Italy. Corsican provenances made the expected slow start; they may catch up the Calabrian provenances at a later stage.

Lodgepole pine

Difficulty in obtaining adequate seed supplies from the most suitable seed origins continues to restrict the usefulness of this species in afforestation. In particular, seed of an intermediate type from the Skeena River in northern British Columbia, and coastal provenances from the Queen Charlotte Islands, British Columbia, and Prince of Wales Island, Alaska, have been virtually unobtainable. On a number of highly-exposed trial plantations in North Scotland (including Orkney and Shetland) a provenance from Hollis, Prince of Wales Island, has grown uniformly well and shows excellent colour and needle retention. (See Plate 5 in central inset). Only at Sullom, Shetland, is there some doubt about it forming a crop.

An extensive assessment of needle length was carried out in all four main provenance collections of Lodgepole pine and on other selected sites. The results confirm those of earlier assessments, and give an indication of how much variation is caused by the site, since a number of provenances are represented on four different sites. The coastal origins have significantly shorter needles than the inland origins, while those from the lower Skeena River valley are intermediate in needle length. Very little difference was found between British Columbian and U.S.A. coastal provenances. The longest needles occurred on an Albertan provenance at Culbin, Morayshire, and on progeny from another stand of this origin planted at Millbuie, Easter Ross.

Foliage analysis was carried out by the Macaulay Institute on ten provenances of Lodgepole pine in the Millbuie provenance experiment. Samples were collected from each of the five replications and analysed separately. There was a fairly large variation between blocks, and the differences in percentages of the various nutrients varied significantly between the provenances. The nutrient percentages have been compared with the mean annual height increments, and show a roughly inverse relationship between height increment and the percentage for nitrogen and phosphate. Coastal origins grew rapidly but had low nitrogen and phosphate, whereas the reverse was the case with inland provenances. Percentage of potash was higher in the coastal origins than in the inland ones, which may partly explain the frequently observed yellowish needle colour of inland provenances of Lodgepole pine. The ability of coastal provenances to thrive on poor quality peats may be explained by their efficiency in utilising the small amounts of available nutrients.

Two new Lodgepole pine provenance experiments were planted; on a very exposed and infertile hill at the Forest of Deer in the Buchan district of Aberdeenshire, and at Elibank Forest in the Tweed valley at an elevation of 1,400 feet. These experiments compare thirteen provenances from eleven seed collecting regions in N.W. America at sites where the choice of the correct provenance has been found to be critical.

An experiment was sown with twenty-two provenances at Newton Nursery (Morayshire), using a technique developed by the Geneticist for progeny trials. This aims at reducing errors due to differences in seedbed stocking by lining-out plants into specially prepared beds soon after germination, but its usefulness for provenance work is restricted by the labour of lining-out large numbers of very small plants.

Western Hemlock

The hard winter of 1962/63 caused severe browning and shoot die-back on several of the experiments planted one or two years earlier. All provenances were affected at some sites; at others the Alaskan provenance from Juneau showed less browning and die-back. The future of one or two experiments remains in the balance as the surviving plants are in poor condition and no replacements are left in the nurseries should they fail during the current growing season.

A further experiment was planted in 1963 at Alice Holt forest with the last remaining plants of the same provenances. There were some big differences in survival, northern provenances doing much better than those from latitudes south of 50°N.

Sitka Spruce

Winter blasting also damaged several of the experiments planted in 1960 to 1961. Frost damage in spring 1962 was significantly lower on the Alaskan provenances than on the remaining ones in the section planted in the frost hollow at Glentrool (Kirkcudbrightshire). The Skidegate, Queen Charlotte Islands, provenance was almost as badly affected as the worst provenances from Hoquiam, Washington. These differences in frost damage were not correlated with height.

At Mynydd Ddu in South Wales, on a site at about 2,400 feet, southerly provenances appeared not to have hardened off, and to have succumbed to early winter cold before the onset of the really severe winter weather. Provenances from Alaska were healthy.

Western Red Cedar

The experiment planted last year at Thornthwaite, Westmorland, failed due to drought and other causes, and has been replanted. The parallel experiment at Benmore (Argyll) suffered from the severe winter and shows considerable leader die-back, but should recover.

The same provenances in the south had to remain for a second year in the nursery and were planted out in 1963 in the New Forest (Hants), Thetford (Norfolk), Radnor (Rads.) and Cannock (Staffordshire). The site selected at the last mentioned forest was in a frost hollow.

R.L. and J.R.A.

SPACING

About sixty of the sets of spacing experiments which were planted in 1935–36 continue to be assessed. The sets, of 3 ft., 4½ ft., 6 ft. and 8 ft. square spacings in Norway and Sitka spruce, Scots, Lodgepole and Corsican pine, Japanese and European larch and Douglas fir, are now mostly at second and third thinning stage. Results in terms of total and current increment per acre cannot yet be compared, as recruitment into the lowest measurable size class is still taking place in the closer spacings. An examination of increment of individual trees in relation to their position in the range of girth-classes in the crop, at different spacings, is being prepared by the Management Section for treatment by computer.

D.W.H.

WEED CONTROL IN THE FOREST

Woody Weeds

(a) Ammonium sulphamate

This material successfully killed freshly-cut stumps and stumps with 2–3 years re-growth of *Rhododendron ponticum*, when sprayed at 5 or 10 lbs. per gallon of water at 20 gallons of solution per acre. A wetting agent was added to the mixture. Using a powered knapsack mistblower, the spray was applied in mid-July, in hot sunny conditions. There was very little re-growth a year after treatment on plots sprayed at 5 and 10 lb. per gallon. On plots sprayed at 2½ lbs., all stumps and re-growth were very seriously damaged, and many stumps were killed outright, but there were sufficient sprouts one year after treatment to make re-spraying essential. On plots treated at the higher rate, re-spraying, here and there, would be required only if 100 per cent kill of the rhododendron were needed.

Older bushes of rhododendron up to 15 feet high were sprayed at rates of 1½, 2½, or 5 lbs. per gallon. All concentrations almost completely defoliated the bushes, but many of the biggest branches remained alive and sprouted. Smaller bushes were killed by 2½ lbs. per gallon, but there was usually a little re-growth even at the highest rates.

In another trial in a recently cut area, ammonium sulphamate was applied dry, or in solution at ½, 2, 4 or 8 lbs. per gallon, either to the cut surfaces and the top of the stool only, or alternatively to the area around, avoiding both cut surfaces and the top of stool. The rates of application per acre of treated surface were 200, 800 and 1,600 lbs; treatments were put on in February or June 1962. Good control was obtained with the higher rates of application whether applied dry or in solution. Treatment to the cut surface was most effective, but treatment to the area around the stools also killed or seriously weakened the stools themselves.

Conifers growing close to treated stumps or bushes were often killed outright.

In this work, one serious practical problem is that of ensuring that all stumps are sprayed. Even with the care normally taken in experiments, parts of stumps and layered branches especially, have been missed where stumps are irregularly spaced. It may well be most economical in practice to use a lower rate of application than that giving the best kill, returning in the following year to finish off the weakened stumps and treat those that have been missed.

(b) 2, 4, 5–T

Eighteen medium scale trials of 2, 4, 5–T to control woody weeds and regrowth in young conifer crops were laid out. The nonyl ester of 2, 4, 5–T was applied in late August/early September at 1½ lbs. active ingredient in 16 gallons of water per acre, using a powered mistblower. This method of application was found to be twice as fast as using a hand-pressurised knapsack sprayer in applying the same rate of 2, 4, 5–T in 50 gallons of water per acre. Preliminary reports indicate a good control of woody weeds.

(c) 2, 4–D

At Wareham (Dorset) and Ringwood (Hants), there are extensive areas of young Corsican pine growing slowly in vigorous *Calluna* and *Erica* spp. A block at each forest was treated in late August, 1962 with 2, 4-D nonyl ester at 3 and 4 lbs. acid equivalent at Wareham and Ringwood respectively. The same areas had been given triple superphosphate at 3 cwts. per acre in April, 1962. For comparison, adjacent areas were given diammonium phosphate at 3 cwts. per acre but were not sprayed with 2, 4-D.

All treatments were applied by fixed-wing aircraft.

Preliminary indications are that a 70 to 80 per cent control of *Erica* spp. and *Calluna* was obtained—rather less than hoped for. There was also a little browning of some of the pine. There was no obvious increase in the rate of height growth on any treatment. On the diammonium phosphate plots, needles appeared bigger and darker in 1963.

Herbaceous Weeds and Grass

(a) 2, 6 dichlorobenzonitrile (dichlobenil).

This residual herbicide was applied in April 1962 as a 2½ per cent granule to established herbs and grasses around young Corsican pine in Thetford forest. Dichlobenil applied at 8 or 12 lbs. active ingredient per acre, had by the end of the growing season, reduced the percentage cover of perennial grasses (mainly *Holcus mollis* and *Agrostis* spp.) by 60 to 80 per cent. This effect persisted until the following spring; applications at 2 or 4 lbs. had little effect. The addition of a dalapon spray at 7½ lbs. per acre in 50 gallons of water had no effect on the cover of grasses in the autumn. The Corsican pine were unaffected by any treatment.

Two compounds allied to dichlobenil, and issued by Shell Chemicals under the numbers WL 4926 and WL 5972, were also compared to dichlobenil on ground adjacent to the previous experiment at Thetford. Treatments were applied in early June. The control of grasses in October was better, rate for rate, with WL 5972 than dichlobenil; 8 lbs. of the former per acre reduced the cover of grasses in October by 90 per cent compared with 75 per cent with dichlobenil at the same rate.

(b) Paraquat

This contact herbicide was sprayed on mixed grass and herbaceous weeds in Thetford and Swaffham forests (Norfolk). A good immediate kill of the top growth was obtained with rates from ½ to 2 lbs. per acre but the effect did not last for more than two or three months. Two applications were required during the growing season to eliminate obvious weed competition in the season. There was little effect on weed re-growth in the following year.

Applications were directed to avoid the crop, but small areas of foliage were touched; there was some discoloration, but this had no obvious ill effect on the young trees.

J.R.A.

PRUNING

An experiment in pruning Douglas fir, begun at Durris Forest (Kincardineshire) in 1958, is yielding interesting results in terms of the varying ability of individual trees to grow with severely restricted numbers of whorls. A number of points of possible interest to tree physiologists and breeders have been raised.

D.W.H.

PROTECTIVE MEASURES

Exclusion of Deer

The exposure trials of various synthetic fibres described in the *Research Report* for 1962 have had two new materials added to it. Following disappointing field results from orange polythene netting (60 per cent loss of breaking strength in two years) it was decided to make the first strength tests in the above comparative trial after one summer's exposure.

In these tests of wet twine breaking strength, it was found that nylon, terylene and ulstron (poly-propylene), untreated or surface-treated with preservative, lost more than 20 per cent of their original strength in seven months.

Black polythene was superior to orange polythene, having lost only 5 per cent of original strength, and it appears to be the most promising at this stage.

S.A.N.

Atmospheric Pollution

Sulphur pollution has been recorded by the lead dioxide candle method at a number of sites in the Forth-Clyde valley, commencing in 1956 at Devilla forest and Tulliallan nursery. The object of these gauges was to detect any increase in pollution caused by the large power station at Kincardine-on-Forth, which was expected to emit over 150 tons of sulphur dioxide per day. With the co-operation of the Scottish Gas Board a further series of stations were established around the new Lurgi plant at Westfield, Fife, in 1960. In 1959 the survey had been extended to Lennox Forest, 8 miles north of Glasgow, and in 1960 to two sites on the Slamannan plateau, east of Glasgow, where planting was just beginning, in an area where air pollution was expected to influence tree growth.

So far, possible increases in pollution due to the electricity station and the Lurgi plant are masked by the usual annual fluctuation which is caused by climatic variations; and until both plants are working at full capacity their effect will not be easy to assess. However, the results so far do not indicate an increase in pollution of the order necessary to affect trees adversely. In general, the level of pollution was lowest at Devilla Forest and highest at the Slamannan sites, but even the worst polluted of these was equivalent to only the least polluted sites investigated in the Pennine survey.

As noted in the *Report on Forest Research* for 1960 (page 40), a series of 33 small zinc plates were exposed at a height of 2½ feet above the ground in an experiment at South Pennines (Hebden Royd) Forest. This experiment tests the shelter effect of a circular fence made of laths on trees planted inside and outside it. Four lead-dioxide gauges were erected in a line across the experiment and one zinc plate was sited beside each gauge. The others were arranged along six radii from the centre of the ring fence. Sulphur dioxide in the air reacts with the zinc to give zinc sulphate, and as this is soluble and removed by rain, the loss in weight of the plate gives an approximate indication of the pollution by sulphur dioxide. This method has been used in corrosion studies by Hudson and Stanners (1953).

Previous observations at exposed sites in the Pennines suggested that the rate of sulphation of a lead dioxide candle was affected by the amount of wind flowing round it, very exposed gauges giving specially high records. This has been confirmed by Lawrence (1962), who erected anemometers beside lead-dioxide gauges. The gauges in the South Pennines experiment showed the expected pattern of high values for sulphur dioxide at the most exposed gauge outside the fence, and lowest values at the gauge which is most sheltered by the fence. The zinc plates alongside each lead dioxide gauge gave very similar results and the two are highly correlated. Highly significant differences between monthly periods and between the gauge sites were found using both methods. The results suggest that it may be possible to substitute the extremely cheap zinc plate method, which merely involves accurate weighing, for the lead dioxide gauges which require a chemical analysis costing at least twenty five shillings each month. This would allow a much wider distribution of sampling spots and cut down on the inevitable wastage due to vandalism. The zinc plate method will be tested on a wide range of sites, covering all degrees of atmospheric pollution within which conifers can be expected to grow.

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R.L.

SPECIAL STUDIES

Exposure and Wind

Wind

Reports on wind damage from Commission foresters throughout Britain showed that the winter of 1962/63 had been far less stormy than the previous one; the area damaged in Commission forests was 350 acres, as against 1,200 in the previous year. An interesting point from the survey is the increase in the proportion of trees broken as opposed to uprooted due presumably to the severe winter and frozen ground. Most of the damage reported was done during one severe gale on 16th December 1962 but there have been small areas of damage reported every month.

The investigation of the rooting habits of Sitka spruce by pulling trees over, has been extended to better soils, and a total of twenty-six different sites have now been examined. These studies have confirmed that Sitka spruce rooting is extremely sensitive to soil conditions and that there is a very close relationship between the site and the form of the root system. The root system of Sitka spruce is clearly intolerant of water-logging and anaerobic conditions. On freely-drained sites the root systems are both deep and extensive.

Progress has been made in the wind tunnel studies carried out at the National Physical Laboratory. 256 model trees with brass stems and wire mesh crowns standing about twelve inches high, were used to represent a small block of forest in a seven foot diameter wind tunnel. The models were designed so that their drag coefficient and their surface area were representative of the trees examined last season, in the 24-foot diameter wind tunnel at the Royal Aeronautical Establishment, Farnborough.

The model trees were spaced at 3.125 inches in rows in a 'plot' of 16 x 16 trees. The front four rows were considered to represent the margin of the forest, and tests were done with five different arrangements: uniform; thinned—every alternate tree removed; curved—the corner trees removed so that the margin had a convex curve into the wind; dense—made up of a larger number of narrow crowned 'trees'; and wedge-shaped—consisting of rows of trees, of different heights the shortest nearest the wind and grading upwards towards the 'forest'.

Thirty-six of the 'trees' were fitted with specially designed electrical strain gauge bases so that the bending moment on the tree and the direction of the force could be measured. Observations were then made on the force on each tree with the different types of margin. Large differences were found, with the wedge shape appearing as the most favourable design for reducing the forces on the trees in the crop. Additional studies were made to examine the effect of rides of varying length, small gaps and irregularity of the crop, on the forces on each of the sample trees. The results of these studies will be reported in full later.

A.I.F.

Root Development

Two experiments established in 1935 were designed to compare various types of 'bad' planting, i.e. planting with the tree roots bent at right angles or in a 'U' shape compared with careful planting. These experiments are at Drummond Hill and Clashindarroch and have been thinned several times so that only a few trees remain in each treatment plot. To determine whether initial 'bad' planting affected stability, these remaining trees were pulled over using a winch and dynamometer by the method described in *Report on Forest Research*, 1960. Root investigations done in these experiments six years after planting revealed distinct differences in form of root system between treatments.

However, preliminary inspection of the 'tree-pulling' results indicates that there is little difference in stability between treatments, although this may be due in part to the soil being reasonably deep and freely rooted.

J.A. and A.I.F.

Growth Problems in Pole-stage Spruce Crops

This general problem, which in its widest sense embraces poor root development and hence the special problem of windthrow, is becoming increasingly pressing and raises the question of specifying the limits to the satisfactory growth of spruce crops, both from the biological and the economic viewpoints. Study plots have been established during the year in Harwood Forest (Northumberland), where early growth of Sitka spruce has been good, but where soil and climatic factors are possibly likely to lead to later fall-off in increment.

The phenomenon of top-bending of Sitka spruce, as a symptom of general debility in this species on limiting sites, has received some attention as it may provide an indicator of falling increment before this is apparent in other ways. However, a form of top bending without severe shoot growth reduction has been noticed in parts of West Scotland (e.g. Loch Eck and Glenbranter Forests), in regions previously considered quite satisfactory for the species, apparently in response to sudden exposure after thinning or the cutting of road lines. The development or persistence of this less severe bending will be observed.

It is sometimes assumed that the severe defoliation of Sitka spruce by the Green spruce aphis (*Neomyzaphis abietina*) is a secondary effect on sites where vigour is depressed by limited soil moisture or excessive transpiration. To determine what role this pest can play in reducing increment, an experiment is planned for the Forest of Ae, Dumfriesshire, in which parts of a Sitka spruce crop will be kept free of aphis by periodic spraying during several years. Careful measurements, using band dendrometers, will compare increment at short intervals through the growing season between sprayed and control trees and relate this to the incidence of aphis on the controls. The effect of local climatic conditions which affect moisture relations will also be examined.

D.W.H.

Fire Control

Work on this subject continued on the lines indicated in the previous report, the main emphasis being on the use of sodium alginate and in the development of techniques and equipment of mixing the alginate to form viscous water. There is strong indication that this is a most promising and practical line of research, but complete results will not be available until later; a separate report on the test series will be prepared.

Debarking of Hardwood Pulpwood

Results from the trial on saw log-size oak are not yet to hand, although there is some indication that it has been rather more successful than the previous experiment on material of a similar size. A trial was also conducted on an area of pole-sized hardwoods covering a wide range of species. Diquat was used at the rate of ½ lb. (active) per gallon, and a quick and effective kill of oak and willow was achieved at a cost of approximately 3d per cubic foot, with subsequent ease of peeling; but with no other species were results satisfactory, the bast remaining firmly attached even when some looseness of outer bark was achieved. Alternative techniques may have a more satisfactory effect, but before further effort is devoted to this work results to date will be reviewed and consideration given to possible alternatives.

R.M.G.S.

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POPLARS AND ELMS

By J. JOBLING

POPLARS

Varietal Studies

Varietal Trial Plots

Three plots were planted during the winter, two at Stenton Forest, East Lothian, and one at Dyfnant Forest, Montgomeryshire. A few potentially important clones are still to be included in field trials. These are being tested in the nursery for resistance to bacterial canker, however, and only clones likely to remain free of disease will be planted out.

Selected plots six years of age and over were assessed at major trial areas. A number of Balsam clones, notably *P.* 'Androscoggin', *P.* 'North West A' and *P. trichocarpa* CF, were again seen to be substantially faster growing than any Hybrid black poplar cultivated in Britain or introduced for trial. In the north of England and in Scotland, where the Hybrid blacks are often slow growing, the difference in vigour was usually considerable. Data collected at Brahan Castle Estate, Ross-shire, where volume measurements were completed of ten-year old plots, provide a useful comparison (see Table 6). Here the better Balsam clones are growing well and have a rate of growth comparable with that of Hybrid black poplars on good sites in the south. Twenty-three plots, including fourteen Hybrid black and seven Balsam clones, were assessed. But of the ten fastest-growing clones, only three are Hybrid blacks. Each was represented initially by a plot of 16 trees, at a spacing of 18 feet x 18 feet (134 trees per acre), but occasional deaths have since reduced the stocking in some. Because of variations in soil type and in drainage, reliable comparisons cannot be made between clones whose growth rates are similar. Nevertheless, the greater production of *P. trichocarpa* CF, *P.* 'Androscoggin', *P.* 'Rochester' and, to a lesser extent in this case, of *P.* 'North West A' is well illustrated.

Table 6

POPLAR TRIAL PLOTS – BRAHAN CASTLE ESTATE, ROSS-SHIRE
HEIGHT, GIRTH AND VOLUME AT 10 YEARS

Clone	No. of trees per acre	Average height of crop ft.	Average girth of crop ins.	Basal area per acre sq. ft.	Volume per acre over bark cu. ft.	Mean annual volume increment cu. ft. per acre
trichocarpa C.F.	134	46.5	30	52.0	794	79.4
Androscoggin	134	48	26	39.7	697	69.7
Rochester	134	45.5	25	36.4	695	69.5
North West A	126	48.5	24.5	32.8	561	56.1
trichocarpa G.D.	134	38.5	21.5	26.5	405	40.5
Oxford	126	40.5	20.5	22.6	365	36.5
regenerata R	134	35	20.5	25.1	355	35.5
Casale 65	109	37.5	22.5	23.7	339	33.9
tacamahaca x trichocarpa 37	109	38.5	20.5	20.1	338	33.8
Casale 78	118	34.5	21.5	24.0	329	32.9

None of the Hybrid black poplars listed in Table 6, namely *P.* 'Casale 65', *P.* 'Casale 78' and *P.* 'regenerata R', has a good record in trials. The only reason for their growing slightly faster than the better-known varieties, such as *P.* 'gelrica', *P.* 'robusta' and *P.* 'serotina', is because they are on more fertile ground.

A third experiment was planted at Ledbury, Hereford Forest, to compare selected clones of Grey poplar, *P. canescens*, and its related species and hybrids. Eleven clones of Grey poplar, three aspen hybrids, and two clones of White poplar have been planted on the site during the past four years.

Varietal Collection

No introductions were made during the year and the collection remains at the previous total of 401 clones.

The Populetum at Alice Holt

Ten clones were planted during the winter, bringing the total to 284. Space still remains for nearly 50 clones and planting will continue as plants of recent introductions become available.

Silvicultural Experiments

Spacing

Work was confined to the beating-up of recently planted experiments and the assessment of older experiments. Data from the earliest planted experiment, at Gaywood, Lynn Forest, Norfolk, in 1953, indicate a reduction in growth rate of trees at 8 feet spacing, though not at the wider spacings of 14 feet, 18 feet and 26 feet. Plots at the closest spacing will be thinned before the start of the growing season.

During the past summer a severe attack of bacterial canker was noted in the experiment at Blandford Forest, Dorset, planted in 1954. It has been known for some years that the clone used in this experiment, *P. trichocarpa* x *koreana* was susceptible to canker and that infection might occur as the trees got older. A heavy attack at this stage was unexpected, however, and it is hardly likely that the whole planting will recover. Most trees are infected and no difference in severity of attack was found at the four spacings of 8, 14, 18 and 26 feet.

Pruning

In early summer, initial pruning treatments were applied in a long-term experiment at Cannock Chase, Staffordshire. The planting, of *P.* 'robusta', covers nearly four acres, and is arranged so that trees can be removed for timber testing at different stages during the rotation without affecting the accuracy of the experiment. The treatments, of which there are ten in all, combine severity of pruning with periodicity of pruning. The trees are to be pruned every year or every second or third year, to different proportions of total height, in each case pruning being taken in stages to a maximum height of 25 feet.

A trial was started at Alice Holt Forest, Hampshire, in which vernier girth bands are being used to compare the pattern of radial growth of trees pruned to different heights. The bands were fitted to five year old trees which had grown at a similar rate since planting, and had reached approximately the same total height and breast-height girth when the pruning was carried out. The trees had only been lightly pruned previously and to avoid lower branches and knots the bands had to be placed on the stem only two feet above the root collar. Fitted at the beginning of the growing season, when the pruning was done, the bands recorded girths varying between 13.04 inches and 13.70 inches. The height of the trees varied between 19 and 20 feet. Pruning was taken on different trees to ¼, ½ and ¾ total height, that is to a height of 5 feet, 10 feet and 15 feet respectively. Measurements of girth were taken of all trees during the growing season at intervals of not more than seven days. The trees pruned to only ¼ total height increased in girth at a more or less constant rate throughout the growing season, that is from mid-May until mid-September. The trees pruned to ½ total height grew slowly for several weeks after pruning, and only displayed a vigour comparable with that of the lightly pruned trees from mid-July onwards. The trees pruned to ¾ total height were considerably less vigorous than all others and only showed a comparable growth rate for a short period in mid-season, from the end of July until the end of August. The growth curves of three sample trees are shown in Figure 1. Many observations of this type are needed before reasonable conclusions can be made on the effects of pruning on growth. The present trial will be continued, therefore, and an attempt made to measure the girth increase of differently pruned trees at other points on the stem.

It was also noted that the trees pruned to ¼ total height increased in height substantially more than the other trees, while they produced far fewer, less vigorous, epicormic shoots.

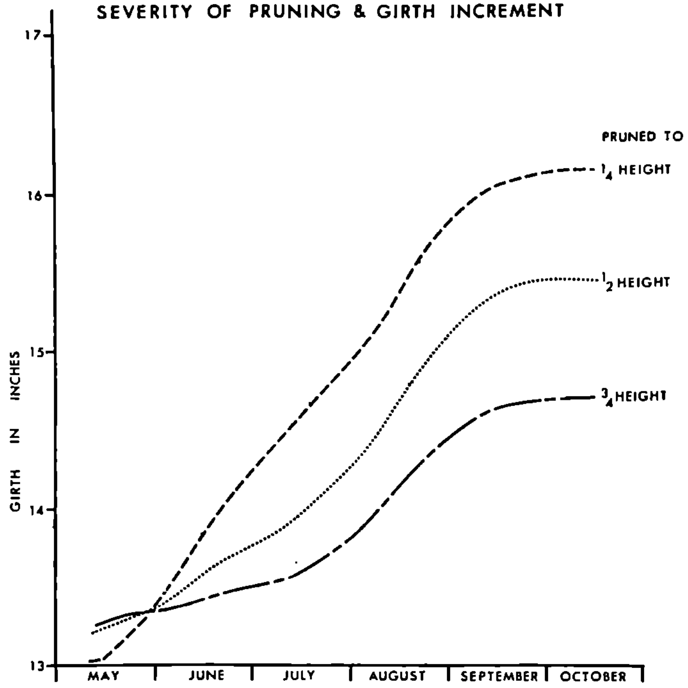

FIGURE 1. Pruning of poplars.
The effect on girth increment of pruning to different degrees.

Nursery Studies

Mist Propagation

Results in 1962 tended to be disappointing. A mechanical failure of the mist unit, cutting off the supply of water, caused the failure of many cuttings before they had rooted. A substantial number of plants also failed after lining-out. Overall, only five plants were produced for every ten cuttings inserted. As in previous years, the aspen species survived least well of any poplar, with a take of only 16 per cent. The hybrid aspens, mainly clones of the cross *P. tremula* x *tremuloides*, had a take of 64 per cent, while the White poplars, mainly clones of *P. canescens*, had a take of 72 per cent. Cuttings of poplars in the *Leucoides* section had a high survival (87 per cent) and, not unexpectedly, nearly all cuttings survived of the few Black and Balsam poplars inserted.

Distribution of Cuttings

Some 20,000 cuttings of the standard varieties were distributed to Forestry Commission nurseries, trade nurseries and private estates during the winter. Additionally, small numbers of cuttings were sent to Northern Ireland, the Irish Republic, Denmark, Holland and India, as well as to research workers in Britain. There was a considerable demand for material of *P. tacamachaca* x *trichocarpa* 32, and not all orders could be met for this relatively new hybrid. The demand for cuttings of the Hybrid black poplars, notably *P.* 'eugenei', *P.* 'gelrica', *P.* 'laevigata', *P.* 'robusta' and *P.* 'serotina', was less than average.

Bacterial Canker Investigation

Planting continued at Fenrow Nursery, Rendlesham Forest, Suffolk, where clones are being tested for resistance to bacterial canker. Fifty-nine clones were planted. The plants will be inoculated with bacterial slime in early summer, using diseased material taken from cankered trees at Ling Heath, Brandon, Suffolk. To test the pathogenicity of bacterial slime obtained from other sources, an experiment was planted during the winter at Mundford, Thetford Chase, Norfolk. In this the trees, of commercially important varieties, will be inoculated with bacterial slime from cankered trees at Fenrow Nursery, at Ling Heath and at Creran Forest, Argyllshire, as well as being inoculated from pure cultures of *Aplanobacterium populi*, one of the causal organisms of canker.

ELMS

Clonal Collection

The collection now contains 76 clones, of which 49 are selections of 'plus' elm trees located in Britain. The stool bed in the grounds of the Research Station contains 58 clones. Of the introductions made during the past year, the most interesting is a selection of Dutch elm, *Ulmus hollandica* var. *hollandica*. This was made in a stand reputed by a representative of the timber trade to have been the best of any in the country before it was partly felled. The trees remaining are of unusually fine form for this variety, while those removed are said to have yielded a timber of high quality.

All recent selections are being raised for inclusion in disease trials and for possible planting in field trials. Additionally, nine clones are being propagated on a relatively large scale for use in silvicultural experiments. All current propagation is carried out under 'mist' using softwood cuttings, when stock suitable for planting out is usually obtained at the end of the second season. Considerable hare damage occurred during the winter in the nursery at Alice Holt. Though plants of a wide range of forest tree species were growing in the same nursery, the hares displayed a strong preference for elm and most other species escaped injury. Rooted cuttings raised for field planting were most seriously damaged.

Propagation

A partial failure of the mist unit in early summer caused an appreciable loss of rooted cuttings. Many plants also failed on lining out, after transfer from the mist unit to the open nursery. The overall survival, of 37 per cent, was considerably lower than in previous years. Normally softwood cuttings are inserted in the mist unit within an hour or two of being removed from the nursery stool or parent tree. An interesting variation was tried during the summer, however, when part of the propagation material was placed in cold store (+ 3° Centigrade) for 16 days after collection. When placed in the mist unit, the cuttings survived better than other lots inserted at the same time, while the plants had a higher survival than usual after lining out. At the end of the season, the plants were several inches taller than others raised with them. A survival of 69 per cent was obtained. This is an encouraging result, deserving experimental study.

A trial started on the rooting ability of hardwood cuttings was only partly informative. The almost complete failure of one of the two clones used inevitably restricted comparison between the experimental treatments applied to the cuttings. But with the better clone, of which 43 per cent of the cuttings rooted, there was some indication that the "take" was improved by placing cuttings in cold store for a three month period at + 3° Centigrade, before insertion. Storage in sand in the open appeared to be rather less beneficial, but there was no indication that soaking the cuttings in water, or an application of a growth hormone, had any effect on behaviour. The cuttings were taken from one-year old leading shoots on hedgerow sucker growth.

Establishment Studies

After lining out, rooted softwood cuttings of most clones of elm grow vigorously. In the first year they will reach a height of two to four feet, and in the second year many will be at least five to six feet tall. Plants of the younger age can be used in the forest, but the older plant is probably best suited for hedgerow and roadside planting because of its larger size. To compare the behaviour in woodland conditions of the two ages, an experiment was laid down in 1962 at Alice Holt Forest. The rooted cuttings lined out for one year were three to four feet tall at planting, and those lined out for two years were five to seven feet tall. All the plants were of the Commelin elm, *U. hollandica* cv. 'Commelin', a hybrid closely related to the Huntingdon elm. Although only one year's results are available a clear difference in behaviour between the two ages of plant is discernible. Though all plants survived, many of the older stock lacked vigour and some died back several inches. Their mean increase in height was less than three inches. On the other hand, virtually all plants of the younger stock grew well, and a mean increase in height of over fifteen inches was recorded. The difference in height increment was so great, in fact, that the mean height of the younger plants was only two inches less at the end of season than the mean height of the older plants. A nitrogen, phosphate and potash fertilizer applied to the trees at planting had no observable effect on growth.

Disease Testing

The Elm disease trial in the Research Station nursery now contains 25 clones, 11 more than last year. Vigorous plants will be inoculated from cultures of the causal fungus, *Ceratocystis ulmi*, during the current season. No additions were made to trials of natural infection in East England.

FOREST ECOLOGY

By J. M. B. BROWN

While the study of the Black pines (*Pinus nigra* and its varieties) in Britain continued as the main activity, an ecological survey of the stormy site of Dunnet Forest, Caithness, occupied a substantial part of the Ecologist's time during the year.

On the eastern shores of Dunnet Bay there is a line of mobile sand dunes, running NNE/SSW which is backed by more or less fixed sand flats, with a main road between the two types of ground. The flats were planted with pines and other trees between 1955 and 1958. Some planting was carried out also on the coastal dunes, where, however, the main work was the fixation of the sand and the consequent protection of the main road from Thurso to north-east Caithness and of the plantations beyond the road. The sand fixation measures, embracing "thatching" (wiring down of brushwood), erection of artificial hedges, planting of marram (*Ammophila arenaria*), have been costly, but on the whole effective. Nevertheless, completion of the work will demand a good deal more effort and thereafter constant vigilance, if occasional breaches are to be repaired before serious damage is done.

On the planted sand flats an attempt was made to estimate the prospects of the plantations as a whole and the relative merits (in relation to the peculiarly severe conditions) of the various species tried. It became evident that, despite the very high values for calcium carbonate content obtained in some parts of the area, the alkalinity of the sand is not the main inhibitory factor at present: deposition of salt spray and the desiccating action of the strong north-west winds appear of overriding importance in this area of stunted early growth and frequent deaths. In the later planting there was a tendency to rely on *Pinus nigra* (of Austrian or Corsican provenance), regarded as more tolerant of alkaline soils than Scots or Lodgepole pine. This raises the question whether Black pine, should it survive the initial hazards, will tolerate the cold general climate of the north coast. The temperature figures appear to give a negative answer, but, in the special conditions at Dunnet, predictions based on experience in the hill lands of central and southern Scotland may be falsified.

Black pines (*Pinus nigra*)

Examination of the many Corsican pine records, supported by further visits to stands where die back disease has been prevalent, have brought further evidence of the importance of summer warmth and good ventilation in aiding resistance to attack. These conclusions have been confirmed by the work of D. J. Read, Hull University Botany Department, who contributes a short account of his studies to this report. They receive some confirmation also from the circumstance that many stands, which were heavily thinned by disease and death in the past, appear to have shaken off the attack and to have resumed slow but healthy growth. It is as if the conditions which favoured the spread of *Brunchorstia* (lack of sun, lack of air movement) were removed by the drastic opening up of the stand. Further evidence has accumulated that this fungus plays a more active role than has been customarily ascribed to it in Britain. On one site where disease appeared before the plantation was ten years old (the 1,000–1,100 ft. high Corrennie section of Pitfichie Forest in Aberdeenshire) material collected in July 1962 yielded, for the first time in Britain, the perfect stage, *Scleroderris lagerbergii* Gremmen.

Stem and branch cankers were also occasionally seen on trees in the Pitfichie Corsican pine plantation. Although not a usual concomitant of die back disease, they have been recorded on several upland sites, including Gwydyr/Diosgydd (Caernarvonshire) where the crowns of two affected 40 years old pines were examined in more detail. It appeared that the youngest affected shoot was that of 1955, and this pointed to the severe cold of February 1956 as a possible factor in canker production. A watch is being kept in the expectation that the severe 1963 winter may have provoked the same, or other, pathological symptoms. Up to the present the only effect of the recent cold weather on *Pinus nigra* appears to be an increased incidence of needle discolouration, particularly on the exposed north-east edges of plantations.

Further examples of death accompanied by honey fungus (*Armillaria mellea*) infection have been recorded in Thornthwaite (Cumberland) and Gwydyr Forests. Although there has also been die-back disease in both localities, honey fungus is in no way restricted to sites where Corsican pine is growing in unfavourable environments. In Alice Holt, Hampshire, deaths have been noted in plantations growing with great vigour. The occurrence of stumps of broad-leaved trees appears to be the common factor: what special soil properties are associated with the incidence of honey fungus infection on Corsican pine has not been ascertained.

FOREST SOILS

By W. H. HINSON, R. KITCHING AND D. F. FOURT

Soil Moisture in Woodlands

Further use has been made of gypsum soil moisture blocks containing metal electrodes, which have proved a useful method of investigating the distribution of soil moisture. The measurement of the electrical resistance of the blocks has posed several problems and these have been solved by the design of transistorized alternating current bridges, the latest of which incorporates a phase-sensitive detector and a moving-coil meter.

Two sites are at present being used for soil moisture studies, a sandy loam at Bramshill and a chalk down at Buriton, both in Hampshire.

(i) Sandy Loam at Bramshill, Hants.

Following up the work on growth and soil drying patterns in Scots pine in which we have collaborated with Dr. Rutter of Imperial College Botany Department, plots have been selected for comparative studies in stands of Corsican pine and Douglas fir. The new plots are at Bramshill Forest, Hampshire, and have similar aspect, exposure and soil. They are only a few hundred yards apart on a deep freely-drained sandy loam derived from the Bagshot beds. Both plots are fully stocked with a top height of 70 to 80 ft. Gypsum soil moisture blocks have been installed at depths of 6 ins., 12 ins., 24 ins., 42 ins., 66 ins. and 96 ins., and replicated at four positions in each plot. Fourteen trees per plot have been fitted with girth bands at breast height, mid-way up the stem and just below the crown at a height of about 40 ft. The girth bands and soil moisture blocks are read at weekly intervals during the greater part of the year, together with the electrical resistance of the stems of selected trees by means of the four-electrode system.

This season the girth increment pattern of Corsican pine was very similar to that of the Scots pine reported last year, but pauses or short periods of below normal increment rate occurred on only three occasions; less frequently than was observed last year on Scots pine. It is tempting to associate this with the moister summer. Douglas fir showed such pauses in increment rate on the same occasions as observed in the pine, but also showed some additional and equally noticeable pauses. These were not common to all the observed trees.

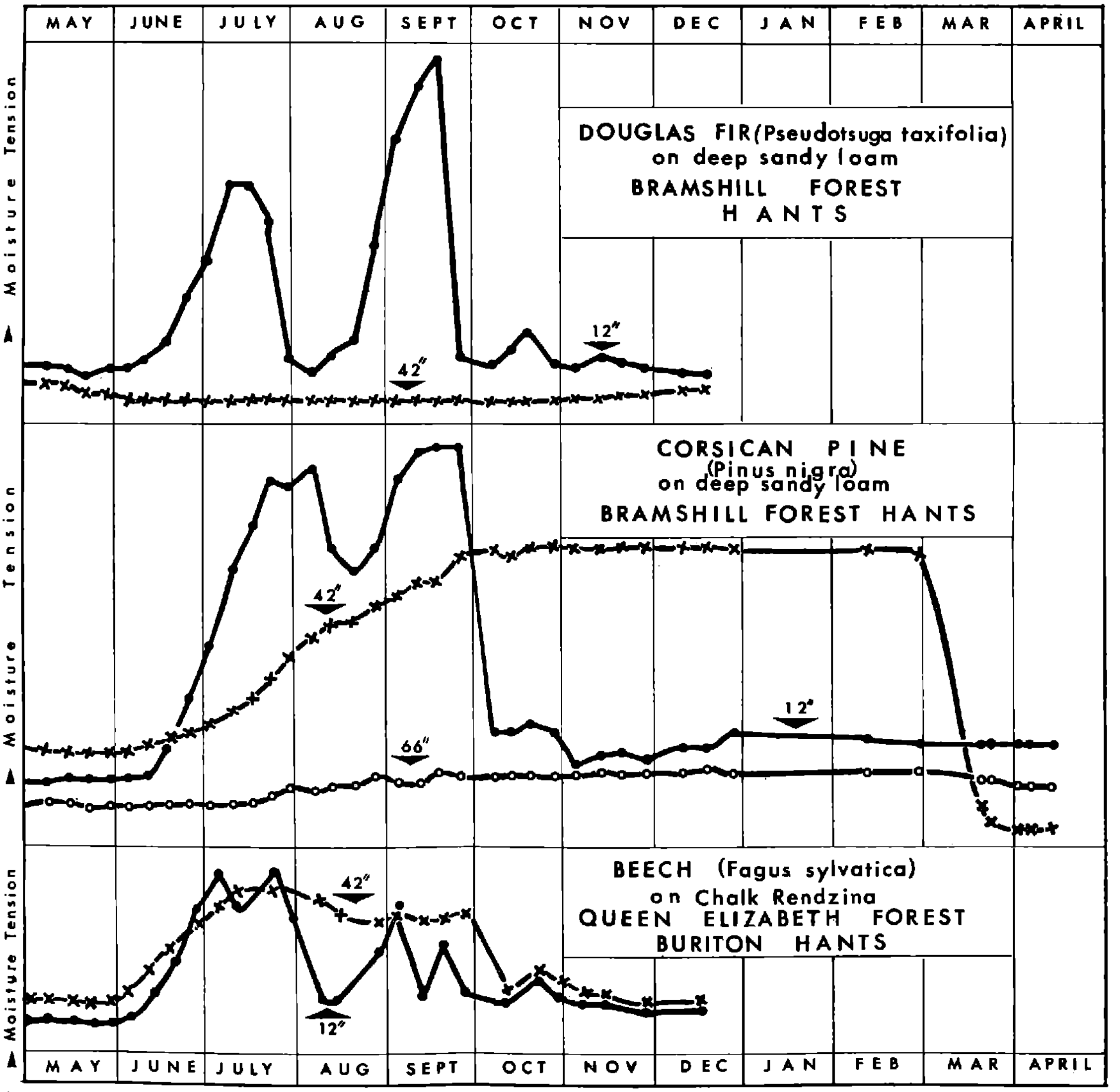

FIGURE 2. Moisture tensions throughout the 1962/63 season under Corsican Pine and Douglas fir on sand, and beech on chalk soils, all in Hampshire.

The top, base and intermediate girth bands usually indicated similar rates of increment, with the notable exception that the pine co-dominants were growing at a rate approaching the dominants at the top, but only at about 30 per cent of this rate at the base. On some occasions growth rate variations were most evident at the top, on other occasions at the base.

The soil drying patterns and estimated evapo-transpiration showed the greatest contrast. On the sandy loams of Bramshill the pattern of soil moisture distribution over the season shows progressive drying from early June onwards, when rainfall lags behind evapo-transpiration demands. The soil dries down to a certsin depth, about 4 ft. to 5 ft. in Corsican pine and 2 ft. to 3 ft. in Douglas fir and below this there is no appreciable change in moisture content (as shown by moisture block resistance readings) throughout the year. (See Figure 2).

The Corsican pine drew moisture from a substantially greater depth of soil than the Douglas fir, but nevertheless brought about somewhat greater soil moisture tensions. The very considerable difference in the moisture regimes will be appreciated from the fact that although the plots started to dry out from field capacity on June 1st, and the Douglas fir site was re-wetted to a similar state by 6th November, 1962, the pine plot did not completely re-wet until about 25th March, 1963. However the magnitude of the soil moisture tensions probably never reached values at which it would be expected to cause moisture stress in the crop.

The electrical resistance of the stems showed well-marked trends rising to peaks over periods of several weeks. In the case of the Douglas fir the peaks of high resistance corresponded with the soil moisture deficit in the top 24 ins. of soil.

(ii) Chalk Down at Buriton

A preliminary study of the moisture relations of chalk soils, using some of the techniques described above, has been commenced at War Down, Queen Elizabeth Forest, Buriton, Hampshire. The plots are situated on the dip slope of the down near one of the highest points at an elevation of 750 ft. The soil is thin, relatively free of drift material and highly calcareous to the surface. The crop is beech planted in 1928 and growing well after a slow start; and for comparison there is a grass plot.

Moisture blocks are in use at 6 ins., 12 ins., 18 ins., 30 ins. and 42 ins. depth at four positions in each plot, and twenty four trees have been fitted with girth bands at breast height. The drying pattern is quite different to that observed on the sandy loam at Bramshill. The main feature on the chalk is the marked tendency for soil moisture movement so that there is normally much less difference between blocks down the profile on any particular occasion (See Figure 2.).

Though both the grass and the tree crop seem to receive moisture from movement in the chalk below the depth of their roots, differences in transpiration between the two crops is reflected by different intensities of soil drying. The significance of the observations is difficult to assess at this stage, but the common assumption that difficulties in the afforestation of chalk downland are mainly due to limitations of such soils to supply moisture may well require modification. The rainfall catch of a gauge at the site for April 1962/3 was 40 inches.

The girth increment of the beech was regular throughout the growing season, except that trees infested with the Felted Beech Coccus, *Cryptococcus fagi*, were severely handicapped compared with clean trees. It is not thought that the grass site ever experienced appreciable moisture stress, nor does it appear that the considerable stress in the beech plot affected its growth at any time.

Electrical Resistance of Tree Stems

Almost any addition to our information on changes in the moisture content of tree stems would be very valuable in connection with current work on soil moisture in relation to growth and physiological moisture stress; such information would also throw light on some aspects of silvicultural differences between species, and on certain entomological and pathological problems. The electrical resistance of tree stems is being investigated as a possible indicator of moisture conditions.

The records obtained by weekly readings with the four-terminal bridge are not easy to interpret. The resistance has been corrected for temperature on the basis of the temperature coefficient of resistance of logs measured in the laboratory, but changes in ionic contents of the sap and in the maturation of new tissue may well also affect the seasonal trend in resistance. However, changes in resistance in the course of a few hours have been observed and these are likely to be due to moisture stress. This possibility is currently being examined, using as material trees of several species growing within half a mile of the Research Station. These trees are connected to the laboratory by field telephone cables and selected by switches.

Measurement of Tree Girths

Improved versions of girth bands have been tested during the year. The original design of vernier girth band was made from untreated aluminium strip. This tended to corrode, especially where the calibration marks occurred. Bands of a soft grade of stainless steel were tried, and have proved quite satisfactory for most purposes, though some 'set' is necessary when fitting. For reading at a distance with binoculars, as in the 20 ft. and 40 ft. positions at Bramshill, and elsewhere where unobtrusiveness is an asset, aluminium strip sprayed with black Araldite paint (AR. 1516) has proved useful. It is possible to read this up to 25 ft. away with 6 x 30 binoculars, in studies where the increments are of interest above breast height. Girth bands are normally read weekly, and the data plotted on calendar graph sheets.

Garnier Gauges at Alice Holt

As in 1961, readings of seepage, and watering, were carried out at about 9 a.m. G.M.T. (See *Research Report* 1962, p. 51). Monthly totals, expressed as inches of water, are derived from the difference between rainfall plus watering addition, and seepage. These are shown, with other data, in Table 7 below. Except in June, the hours of sunshine were lower, and the rainfall higher, than in 1961. The total observed potential evaporation was about 2 in. less in 1962 than 1961, and rainfall was also down by this amount, although the growing season rainfall from April to September was 13.64 ins. in 1962 and 12.50 ins. in 1961.

The observations are communicated to Mr. F. H. W. Green of the Nature Conservancy, Aviemore, who is summarising like data for the Meteorological Office publication *British Rainfall.*

The commencement and closure of the observation year were dictated by frost and snow on the site.

Correspondence between the measurements from the two installations is, as usual, less close between months than between years. Details appear in Table 7.

Table 7

GARNIER GAUGE RECORDS. ALICE HOLT. (1962)

Month	Potential evaporation (inches) (P.E.)			Rainfall inches at Alice Holt	Sunshine		Remarks
	Lysimeters		Calculated value *		Daily mean hours (from Tables) *	Daily actual hours 1962	
	A	B					
January	0.555	0.725	0.25	5.14			Started
February	0.333	0.320	0.40	0.49			Dec. 29/61
March	0.980	1.030	1.00	1.39			
April	1.410	1.520	1.95	1.93	5.05	5.01	
May	2.370	2.405	2.85	2.37	6.20	5.37	
June	4.160	4.210	3.90	0.29	6.90	8.52	
July	4.025	4.150	3.20	1.32	6.50	4.71	
August	3.610	3.370	2.80	3.42	6.30	5.66	
September	2.105	1.755	1.68	4.31	4.60	4.78	
October	0.950	0.800	0.65	1.61			
November	0.135	0.060	0.20	3.00			Ended
December	0.085	0.045	0.15	2.77			Dec. 19/62
Totals (1962)	20.715	20.270	19.12	28.04			
Totals (1961)	22.505	22.580	19.38	30.18			

* See Technical Bulletin No. 4, Ministry of Agriculture, 1954.

Drainage Studies

It is doubtful if sufficient attention has been paid to the planning of drainage works for afforestation; the depth and spacing of drains has all too commonly been inadequate or the alignment faulty, and there has been a notable absence of any generally agreed code of practice.

Formal drainage experiments on peat and mineral soil are mentioned on pages 24 to 25 of this *Report* and if such experiments could be replicated on a sufficient variety of sites the crop assessment data should ultimately yield a rational basis for the prescription of drains. However, so as to provide some practical advice immediately, and further information at an early date, other steps have been taken.

An attempt has been made to elucidate the effect of ground slope on the proper drain spacing by means of models and calculations. The results of this work have already been incorporated in practical recommendations. It appears that the ground slope may well be the most important single factor in determining the most suitable drain spacing for typical forest land, but it is intended to improve the prescription as soon as methods can be devised to assess the significance of other factors, particularly rainfall, evaporation, and soil material. With this aim in mind, the drainage experiments need to be assessed independently of possible crop responses. Accordingly recording flow gauges have been designed for use in forest drains. A number of these are now in use at the drainage experiment at Halwill, Devon, together with an array of boreholes in which the water levels are observed at fortnightly intervals. This data, together with local rainfall records, should give quantitative information on soil changes and permit a complete analysis of the performance of the experimental drainage system. (See Plate 1 in central inset).

Chemical Analysis

Analysis of soil samples and needles in connection with fertilizer and nutrition work has been a routine but important part of the work of the soils section. A new method of analysis being used is atomic absorption spectroscopy. This technique is not only sensitive but also relatively free from interference effects from unwanted elements. Efforts in this laboratory have been towards the design of a double-beam system in order to improve the stability of the equipment and the limits of detection. A provisional patent has been filed for the design of an atomic absorption burner, and negotiations are in hand with the National Research Development Corporation to exploit the design.

FOREST GENETICS

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

Survey of Seed Sources

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 existing varieties and cultivars. The greater part of the survey work in 1962 was done in plantations between twenty and thirty years of age with the object of increasing the acreage of seed sources of Norway and Sitka spruce and Lodgepole pine. The work yielded thirty-five classified seed sources totalling 433 acres.

Formation of Seed Stands

The next step in the process of improving the genetic quality of seed collected in Britain is to convert the best *seed sources* into *seed stands* or *seed production areas*, in which all the phenotypically poorer trees are removed, thus leaving isolated the crowns of the finest trees for seed collection purposes. (See Plate 6 in central inset). This conversion of seed sources into seed stands continued steadily in 1962, and by the end of March, 1963, 813 acres had been wholly or partially converted into seed stands. Table 8 summarises the progress by species and it will be seen that most progress was made with Scots and Corsican pine, Japanese larch and Douglas fir. Complete N.P.K. fertilizer has been applied to the ground below the seed trees in twenty-six acres of pine seed stand, with the object of increasing seed production, the elements being applied at the rates of 100 pounds per acre of nitrogen, 50 pounds of phosphorus and 100 pounds of potassium.

Table 8

PROGRESS IN THE FORMATION OF SEED STANDS
(AT MARCH 31st 1963)

Species	*Area (acres)*
Scots pine	334
Corsican pine	174
Lodgepole pine	35
European larch	10
Japanese larch	59
Hybrid larch	9
Douglas fir	70
Norway spruce	5
Sitka spruce	4
Silver fir	4
Western red cedar	24
Oaks	54
Beech	31
Total	813

Selection of Plus Trees

The selection and propagation of outstanding phenotypes (Plus trees) and other trees of more specialised interest (Special trees) was continued. The total number of Plus and Special trees of all species that has been marked and recorded is now 3,439 and this total includes 141 'foreign' plus trees which are represented in Britain by clones of grafted plants or rooted cuttings.

The procedure for selecting Plus trees of Sitka spruce has been extensively revised and now includes standards for wood properties provided by the Wood Anatomy Section of the Forest Products Research Laboratory at Princes Risborough. The assessments of the characters of the Plus trees are being recorded on punch cards and the enlarged programme for breeding Sitka spruce involves the screening of about 1,500 candidate Plus trees for their growth rate, growth habit, health and wood characteristics.

Formation of Tree Banks

The establishment of the National Collection of Plus and Special trees of two-needled pines, the larches, Douglas fir, the spruces and beech continued during the year. About half of the Plus and Special trees of these species are now represented in two tree banks by clones of grafted plants or rooted cuttings. Tree banks of Western red cedar will be planted in Spring 1964, and similar collections of clones of Western hemlock and Lawson cypress are also planned.

The tree banks serve several purposes. First, the genotypes of the Plus and Special trees are preserved against loss by windblow, fire or felling; second, the clones of grafted plants and rooted cuttings are brought together into convenient centres so that controlled crosses and phenological observations may easily be made; third, there is the opportunity for a second stage of selection which is proving very useful for some species. The older Scots pine tree banks at

Alice Holt, Hampshire, and Newton Nursery, Morayshire, are now being used for controlled test crosses and are proving very convenient for this work.

Vegetative Propagation

As in previous years, grafting and the rooting of cuttings were used to raise clonal material for inclusion in tree banks, field tests and seed orchards. The final total of grafts attempted during the spring of 1962 was 13,673 and the number of successful grafts surviving to the spring of 1963 was 8,117, representing 1,061 parent trees. The overall success was fifty nine per cent.

A summary of the progress made in grafting during the five years 1953–57 was presented in the Report on Forest Research for 1958 and it is now possible to present a similar summary for the period 1958–62. This is done in Table 9.

Table 9

NUMBER OF GRAFTS ATTEMPTED AND SUCCESSFUL 1958–63

Year	Number of trees Represented	Number of grafts Attempted	Number surviving to following year	Percentage success overall
1953–57	1,689	48,361	31,843	65.9
1958	682	12,727	8,856	69.6
1959	622	14,256	9,322	65.3
1960	473	13,373	9,060	67.8
1961	390	10,942	6,829	62.4
1962	1061	13,673	8,117	59.4
1958–62	3,228 (1)	64,971	42,184	64.8

Note.—(1) Some plus trees have proved difficult to graft or the clones of grafted plants have failed to survive planting in the field; thus several attempts have been made to propagate them.

In general, the percentage success overall has been maintained, although the peak success of 81.7 per cent in 1956 and 77.9 per cent in 1957 have not been attained since. The main reasons are that relatively more grafting has been done outdoors on nurseries or seed orchard sites, while the more difficult spruces and Lodgepole pine now make up a higher proportion of the grafting. There is room for considerable improvement in the technique of grafting the spruces.

Controlled Crossing and Progeny Testing

Controlled crosses are made for several purposes, and the nature of the crossing pattern employed changes with the object of the work. Controlled crosses between individuals of the same species are done to identify those Plus and Special trees which combine well with others to produce good progenies, that is, those which possess good combining ability. Another object of crosses between individuals within a species is to determine the heritability of the desired characters, heritability being defined as that portion of the variance observed in the progenies which is due to genetic factors.

The breeding programmes for the two-needled pines and the larches have now reached the stage when a sustained series of controlled crosses and progeny tests are required to identify trees with good combining ability, make estimates of the heritability of the important characters, and from these estimates determine the genetic gain that can be expected from various breeding procedures. Much effort has been devoted during the past four years to improving techniques of controlled crossing and progeny testing.

Formation and Management of Seed Orchards

Seed orchards consisting of clones of grafted plants derived from Plus trees of Scots pine, Lodgepole pine, European larch, Douglas fir, Western red cedar and beech have been formed, both to produce seed and provide a means of further improvement of these species. Seed orchards comprised of clones of European and Japanese larch have also been planted to produce seed of the first generation Hybrid larch, *Larix x eurolepis*. There are now 204 acres of seed orchards in Britain, 176 acres being maintained by the Forestry Commission, while twenty-eight acres are on private estates. The greater part of the total acreage is accounted for by the ninety-four acres of Scots pine seed orchards and seventy-one acres of larch seed orchards.

In 1960, an experiment was set up in a seed orchard containing twenty clones of Scots pine and situated in Bradon forest, Wiltshire, to compare the effects of mulching, fertilizers, weed suppression by polythene sheets, and three chemical weedkillers (simazine, dalapon and pentachlorphenol) on the growth rate and flowering of Scots pine grafts. This experiment has been run for three growing seasons; mulching with hop waste has emerged as a treatment with a beneficial effect on the production of female flowers and cones. The hop waste, which is a by-product of the brewing industry, was applied as a mulch, one yard square and six inches deep, around the bases of the grafted seed trees.

Most Scots pine grafts produce crops of female flowers and cones soon after grafting and planting-out in seed orchards and tree banks. These grafted plants also grow slowly in their early years and a point of some interest is whether the early growth can be encouraged by removal of the female flowers soon after their appearance. Observations were made in 1961 and 1962 on 126 grafts between one and three feet tall, the cones being removed in both years from half the grafts. The assessments of height and diameter growth suggest that the growth of small grafts is appreciably reduced when the flowers are allowed to develop into cones. Also when the cones are removed there is increased flowering in the following year. These results are being followed up in more detailed and precise experiments.

Other Work

The flow of enquiries from Forestry Commission and outside sources continued. Most of these concerned vegetative propagation by grafts and cuttings, the layout and management of seed orchards and the selection and treatment of seed stands. Technical advice was given to the Scottish Forest Tree Seed Association and the Forest Tree Seed Association of England and Wales.

FOREST PATHOLOGY

By D. H. PHILLIPS

Death and Decay Caused by Fomes annosus (Fr.) Cooke

In work on the control of the fungus *Fomes annosus*, particular emphasis was placed on the field testing of chemicals to replace creosote in stump protection, and (in the case of pine) on the development of a technique of biological control using the competing fungus *Peniophora gigantea* (Fr.) Massee. Excellent results were obtained with a number of chemicals. Particularly good protection was given by sodium nitrite, but polybor and diquat also gave good results. The chemicals were all used as aqueous solutions. The trials are now being extended into the forest, with a view to the possible introduction of one of these materials in place of creosote.

When pine stumps were inoculated with *P. gigantea* by painting with a spore suspension, they were completely protected from airborne infection by *F. annosus*. Good results were also obtained when pine stumps whose roots were already infested by *F. annosus* were inoculated with *P. gigantea*, which limited the further growth of the former fungus. Work is therefore being done on the production of cultures suitable for routine use, and investigations are being extended into the forest, where user trials are being carried out.

Several experiments on the eradication of *F. annosus* infestations have been laid down, and the results of a preliminary assessment of the first of these trials is now available. In this early experiment, the infested stumps were removed merely by winching, and much infested root material therefore remained in the soil. Nevertheless, results so far show that, six years after replanting, in control plots in which the infested stumps were left in the ground, 36 per cent of the plants have been killed by *F. annosus*, while in plots from which the stumps were removed, the fungus has killed only 13 per cent of the trees. More efficient means of stump removal are now available, and may lead to better results than those so far obtained. In the above experiment, various chemicals were also used to treat infested stumps, but results of chemical treatments were much inferior to those given by stump removal.

Needle Blight (Didymascella thujina (Dur.) Maire, syn. Keithia thujina Dur.) of Thuja

Following the success of previous cycloheximide fungicide trials against infection of *Thuja* nursery stock by *Didymascella thujina*, further experiments have been carried out with cycloheximide and its semicarbazone derivatives. The materials used were two American commercial formulations of cycloheximide (Actidione BR and Actispray), and an experimental 1 per cent wettable powder formulation of semicarbazone. When applied in March, all three materials markedly reduced infection. Actidione BR was most effective, but at all concentrations above 5 parts per million it caused damage to the plants. The fungicidal effect of Actispray increased with concentration up to 85 p.p.m., at which concentration the plants remained undamaged. Semicarbazone was slightly less effective, and control of the disease increased up to a concentration of 100 p.p.m. without symptoms of phytotoxicity.

Phytotoxicity trials were carried out on uninfected *Thuja* transplants, and they confirmed the fact that Actidione BR is phytotoxic at low concentrations of 5 and 25 p.p.m. Actispray and semicarbazone at 170 p.p.m. and 200 p.p.m.

respectively produced limited chlorosis at the base of leaflets, but this had very little effect on the growth of the transplants. At 85 p.p.m. Actispray produced a very slight, almost indefinable difference in the appearance of the treated plots, without affecting the general growth of the plants. The results of these experiments indicate that Actispray (which is not yet marketed in Britain) would give a safe and effective control of Needle blight.

Grey Mould (Botrytis cinerea Fr.) on Seedlings

In September 1962, heavy infection of Sitka spruce seedlings by *Botrytis cinerea* was observed in Maelor Nursery, Flint. Many dead roots were found on affected seedlings, and it was considered that death of the roots might have been a factor predisposing the seedlings to infection by *Botrytis*. Usually, infection of conifer seedlings by *B. cinerea* occurs only following damage or serious reduction of vigour caused by other adverse conditions, very commonly frost. Experiments are to be carried out at Maelor, where autumn infection by *B. cinerea* occurs fairly regularly, to examine the effect of soil fungicide treatments against root pathogens on the incidence of damage by *Botrytis*.

Resin Top Disease (Peridermium pini (Pers.) Lév.) of Scots Pine

Losses from Resin top disease in Scots pine have recently caused increased concern to foresters of both State forests and Private estates in the Moray Firth and Spey Valley areas in Scotland. In May and June 1962, a number of the affected forests and estates were surveyed, and field observations made on the incidence and pattern of infection. Although Scots pine crops of all ages were attacked, infection was generally most serious in crops between 25 and 40 years old. The survey showed that vigorous plantations were more severely damaged than less vigorous or checked crops, and that within any stand the incidence of infection was highest on dominant or co-dominant trees. At the present time very little is known on the infection biology of *Peridermium pini*, and it is hoped to initiate research on this subject in the near future.

White Pine Blister Rust (Cronartium ribicola, J. C. Fischer)

In May and June 1962, a careful examination was made of twenty experimental forest plots of *Pinus strobus* planted in 1953 and 1954. The observations suggested that a very high proportion of infection by *Cronartium ribicola* in these plots had developed as a result of infection of the plants while still in the nursery. The planting stock was raised at four nurseries, at Benmore (Argyll), Inchnachardoch (Inverness), Newton (Nairn) and Kennington (Oxford). Only two of the forest plots, those at Kilmun and Kilmichael, were severely affected by Blister rust, and both of these were supplied with plants from Benmore Nursery, in which black currants were present, and in which transplants left in the nursery developed typical *Cronartium* lesions in 1955 and 1956. The lesions produced on trees at Kilmun and Kilmichael were almost entirely confined to the base of the stem from ground level to a height of 9 inches to 1 foot. A very low incidence of this basal type of infection was also recorded in plots supplied from other nurseries. In all cases, infection on other parts of the trees, which was thought likely to have resulted from transference of infection from black currants near the plots, was of very low incidence, and was only recorded in plots in which the basal type of infection was also present.

The data as a whole suggest that the risk of *Cronartium* infection in *P. strobus* plantations more than a mile from black currants may be less than has been previously thought, and emphasize the importance of ensuring that only rust-free stock is raised for planting. Further work is being carried out on the chemical protection of *P. strobus* nursery stock, and on the control of White pine Blister rust in general.

Decay of Conifers Associated with Extraction Damage

In 1961 and 1962, detailed examination was carried out of the amount of extraction damage, and of associated decay on standing trees, in selected plantations of spruce and larch in five Scottish forests. Most of the crops concerned had been planted before acquisition by the Forestry Commission, and all had been regularly thinned, and were on moderate to steep slopes. Observations indicated that with damage to the main lateral roots and stem bases there was an increased incidence of decay with increasing size of the extraction wounds. The rate of extension of decay in the stem varied with the fungus and the tree species concerned. Both Norway and Sitka spruce were more susceptible to decay than was larch, and the decay in spruce caused by *Stereum sanguinolentum* (Fr.) Fr., the fungus most commonly isolated, was recorded as developing at a rate of up to 1 foot per year. The results obtained so far clearly indicate that, as the as yet predominantly young Commission plantings mature, the decay losses resulting from wounding during extraction may be expected to increase considerably, and that serious consideration should be given to any modifications in extraction technique and any other measures likely to reduce these losses.

Blue Stain in Pine

Experiments in Thetford Chase on the control of Blue stain damage developing immediately after the felling of pine have been carried out jointly with the Mycologist of the Forest Products Research Laboratory, Princes Risborough. The results have shown the importance of the relationship between the incidence of Bark beetle damage to logs and the subsequent development of Blue stain. In the year following the setting up of the first experiment in July 1961 a marked periodicity in the development of Blue stain was noted, with a very low development of stain on logs produced during the late autumn and winter months. Various chemical treatments were applied to logs immediately after felling. During the spring and summer, a considerable degree of control of Blue stain was achieved by whole-log spraying with 2 per cent D.D.T. Whole-log spraying with a combined insecticide/fungicide spray gave slightly better results. An experiment carried out in June 1962 showed that the effectiveness of whole-log combined insecticide/fungicide spray treatments decreased progressively with delayed application of the treatment from 1 day to 10 days after felling.

Crumenula sororia Karst on Corsican Pine

In 1961 it was observed that stem and branch cankers occurred on some 50 per cent of the Corsican pine planted in 1952 and 1953 in an area covering three compartments of Ringwood Forest. The area concerned was on impoverished silty gravel with badly impeded drainage, and was covered by a rank growth of *Calluna*. The whole crop was severely checked. Fructifications of *Crumenula* *sororia* Karst. were present on a very high proportion of the cankers. Observations in Ringwood and other forests in South-West England indicate that infection by this fungus is associated with extremely low vigour of the affected plants. In 1962, large areas of the affected crop were treated from the air with diammonium phosphate or with triple superphosphate plus 2,4–D. Transects have been laid down to measure the response of the crop (which includes Scots as well as Corsican pine) to these treatments, and to observe the development of *Crumenula* infection.

Group Dying of Conifers (Rhizina inflata (Schäff.) Quél.)

Observations were continued at Muirburnhead (Buccleuch Estates Co., Ltd.) in Dumfries-shire, where deaths of groups of Sitka spruce followed fires lit in a plantation in 1955. Activity by *Rhizina inflata* had further declined, and most groups were static. Abnormal fructifications, thought to be affected by a hyperparasite, were again found. Windblow had started at some of the gaps caused by Group dying.

No appreciable damage was found to conifers in their second year on ground on which *R. inflata* had colonised sites of fires made in clearing the ground for planting.

Top Dying of Norway Spruce

Observations on this disorder were continued at Knapdale. No pronounced increase of foliage symptoms was found, but growth of trees whose leaders were sharply reduced in 1961 was again markedly poor.

Bacterial Canker of Poplar

A ten-year series of annual inoculation tests for clonal susceptibility to Bacterial canker was assessed, and the accumulated data for the period were summarised for analysis. In one test area, natural canker was found on a number of clones that had appeared resistant to infection by inoculation. A final test bed was added to this series, and inoculation carried out.

Elm disease (Ceratocystis ulmi (Buism.) Moreau, syn. Ceratostomella ulmi (Schw.) Moreau)

Work on clonal selection, propagation, and testing for resistance was continued in collaboration with the Silvicultural Section.

Drought Crack

Earlier investigations into the timber properties of Sitka spruce showed the hidden importance of Drought crack. Species of *Abies* are of particular interest pathologically because they are resistant to attack by *Fomes annosus*, but they also are prone to crack following drought. *Abies* species are therefore being studied to examine the occurrence of Drought cracking in them, and to determine the effect upon it of site factors, methods of management, etc.

Advisory Queries

Two hundred and sixty-two enquiries were dealt with during the year, 115 from Commission forests and 147 from Private estates and the general public. The queries received during the year are summarised below.

Frost, winter cold and drying winds in the winter of 1961–2 caused damage to trees, and gave rise to many enquiries in the ensuing season. Foliage damage to conifers was seen especially on species of pine, but occurred also on Norway and Sitka spruce, Lawson cypress, cedar, *Sequoia* and Douglas fir. Die-back thought to be caused by exposure was seen on oak and cypress. Winter cold also gave rise to stem and bark damage, which was noted especially on willows and poplars. In most cases, dead areas of bark were present, but sometimes small cankers occurred on main stems, or (on willows) on branches and twigs. On poplars, large open splits and cankers appeared on the lower parts of the stems of trees on some frosty sites.

Dry weather following planting, and continuing for much of the summer, caused losses among young plants in many areas. Japanese larch was especially affected, but Norway spruce and Scots pine were also damaged. In one area, newly planted and one-year-planted *Thuja* trees had been unable to produce adequate root systems, and showed heavy losses, whereas adjacent plants set out two years previously had produced better roots, and were unaffected. Drought damage was also seen on mature trees, and was recorded on cedar, oak, beech, and Sweet chestnut.

In spring and early summer, severe browning of needles of Norway spruce transplants was noted in several nurseries. The damage (which in some cases caused considerable loss) appeared to result from some interaction between drought and certain inorganic fertilizers. Symptoms thought to be caused by potash deficiency were noted on pines and spruces in some nurseries.

The dry summer weather was unfavourable to the development of most of the diseases of foliage caused by fungi and other parasitic organisms. Some records of these parasitic diseases (both of leaves and of roots, stems and shoots) were made in the course of advisory work, however. Damping-off occurred on seedlings of pines and Silver firs, and Grey mould (*Botrytis cinerea* Fr.) damaged young plants of *Sequoia*, Norway and Sitka spruce, larch and *Tsuga*.

Of the major root and butt-rotting fungi, *Fomes annosus* (Fr.) Cooke was noted in Scots pine and Sitka spruce (and on many other conifers in the course of research work), *Armillaria mellea* (Fr.) Quél. (the Honey fungus) in Scots and Corsican pine, Norway and Sitka spruce, *Tsuga* and *Sequoiadendron*, and in elm, poplar and willow, while *Polyporus schweinitzii* Fr. occurred in Sitka spruce. *Stereum sanguinolentum* (Fr.) Fr. was present in a *Tsuga* tree that appeared to have been damaged by frost.

Among the rusts, *Peridermium pini* (Pers.) Lév., *Melampsora pinitorqua* Rostr., and *Coleosporium senecionis* Fr. were all observed on Scots pine. The first of these caused considerable damage locally. *Chrysomyxa abietis* Unger was seen on Norway spruce.

A few cases of Needle blight (*Didymascella thujina* (Dur.) Maire) were recorded on *Thuja* in nurseries. *Sclerophoma pithyophila* Höhnel was observed on needles of Scots pine, and *Rhabdocline pseudotsugae* Syd. on Douglas fir.

Some cases of Elm disease (*Ceratocystis ulmi* (Buism.) Moreau) were brought to our notice, but this disease did not appear to be causing severe damage in the year under review.

Bacterial canker of ash was reported to be causing serious damage in one planting in South-West England.

FOREST ENTOMOLOGY

By D. BEVAN

Pine Looper Moth (Bupalus piniarius)

All forests, excepting Cannock Chase, reported a low density of Pine Looper pupae over the winter 1962/63.

At Cannock, during the autumn of 1962, defoliation could be seen in some areas, but no remedial measures were considered necessary. Current counts of pupae, however, indicate that widescale heavy damage is likely in 1963 if the present population develops without mishap.

Of the 43 compartments included in the normal annual survey, 12 have counts of pupae over 30 per sq. yd. compared with only 2 compartments at the same time last year. Including the extra compartments sampled in an extension survey, a total of 39 out of 99 are found to have pupal populations in excess of 20 per sq. yd., the highest compartment mean being 84 per sq. yd.

Data for "forest mean" (i.e. the average pupal count per sq. yd. of the compartments sampled in the normal survey) show a rise, from 7 in winter 1961/1962, to 17 now.

Parasitism of overwintering cocoons by *Cratichneumon nigritarius* is low, tending to be rather higher in compartments with relatively low counts of pupae (vide Bevan, Rep. For. Res. For. Comm. 1954, p.163). The degree of control accomplished by this species in its spring attack (vide Davies, Rep. For. Res. For. Comm. 1961, p.176–181) is being investigated.

Larch Sawfly: Anoplonyx destructor

Studies of the Larch sawfly continue. The life cycle of *Labroctonus westringi*, a parasite of both *A. destructor* and *Pristiphora laricis*, is now understood. Increment loss caused by *A. destructor* defoliation continues to be studied at Drumtochty.

Douglas Fir Seed Fly: Megastigmus spermotrophus

A study plot has been set up in the New Forest to observe movements in population over the years and to investigate any relationship of these fluctuations to quality of seed year. A survey of Douglas fir stands, involving sampling in 8 areas distributed over the country, was made and is to become an annual feature. Over half of these were found to have percentages of infested seed in excess of 50% and some of them as high as 90%. 15% infestation was the lowest recorded for any area.

Pine Weevil: Hylobius abietis

Investigation into the phytoxicity of materials for use in dipping treatments of transplants against Pine weevil continue. The trials include complete-dipping with a view to providing protection against both weevil and the *Hylastes* beetles. It was apparent that in experiments carried out in winter 1961/62, time of treatment and planting had considerable bearing on survival.

Ambrosia Beetles: Trypodendron lineatum

Plans for further investigations into the factors causing variations in susceptibility of logs to Ambrosia beetle attack were thwarted by a nearly complete disappearance of this insect from Western Scotland. Further work will depend on the resurgence or otherwise of damaging populations.

Other Insects

The Clay-coloured weevil, *Otiorrhynchus singularis*, has been unusually common this year and has caused serious damage to transplants in the New Forest, Coed Morgannwg, Rheidol and Quantock Forests. Lighter damage is reported from several areas in Scotland and elsewhere. The tree species damaged include Sitka, *Tsuga*, Douglas and *Thuja*. An interesting infestation of the small weevil *Braconyx pineti*, occurred at Glencoe Forest, and caused light defoliation of 8 year old Lodgepole pine. (See Plate 4 in central inset).

71 enquiries were received from outside the Forestry Commission this year and 180 from within.

MAMMAL RESEARCH

By JUDITH J. ROWE

Control

Investigations of methods of Grey squirrel control are carried out jointly with the Infestation Control Laboratory of the Ministry of Agriculture, Fisheries and Food.

In Scotland, poisoning trials using warfarin were continued. Field trials in 1962 showed that wheat was a practical alternative to peanuts as a poison bait. Laboratory investigations in 1963 have shown that it is possible to introduce a soluble salt of warfarin into the germ of whole maize which is a cheap and readily acceptable bait. Field trials of the poisoned maize are being conducted in summer 1963.

A study is being made of the degree of protection afforded by cage-trapping just prior to the damage period (May to July) in eighty acres of non-isolated mixed hardwood/conifer woodland with a history of severe damage. Re-trapping at the end of the damage period in 1962 showed that re-colonisation, mainly by young squirrels, had occurred, but no fresh damage was present. This is being repeated in 1963.

Preliminary trials of a German preparation for control of the Fieldvole, *Microtus agrestis*, are being carried out under the Notifications and Clearance Scheme of the Ministry of Agriculture.

Investigations of various aspects of deer biology relating to their control, including methods of age determination, rates of increase and the movements and behaviour of a marked population, are being initiated.

Protection

Chemical repellants have been the subject of further trials. Special attention is being paid to the problem of finding suitable 'stickers' since one of the chief drawbacks to the large-scale use of repellants is lack of persistence. This is obviously limited by the rate of degradation of the materials but their effective life is prolonged by mixing with adhesive before application. Various latex derivatives have shown promise in this field.

Investigations of the longevity of various types of synthetic fencing materials are being continued in Scotland. It appears that where rabbits and hares and/or sheep as well as deer must be excluded from young plantations, three or four feet of blackened polythene netting over standard rabbit/sheep fencing is a cheaper alternative to a deer fence of the normal specifications. Suitable electric fence specifications for the protection of plantations and for the exclusion of deer from neighbouring agricultural land are being investigated.

Preliminary trials were made of metal funnels supported three feet from the ground by two stakes for sampling beech seed. Results showed that, under conditions such that there was no predation by rodents or pigeons, there was no difference between the amounts of seed collected in these and in ground quadrats of the same size. The technique will be used in autumn 1963 to investigate the importance of predation by small mammals, squirrels and pigeons during the period of seed fall in two genetically important selected stands of beech.

Questionnaires

Replies to the annual squirrel questionnaire for the year ending September 1962 showed that the expected decrease in Grey squirrel numbers and damage had occurred in England following the poor seed crop and high squirrel numbers of 1961. In Wales there was a slight increase in numbers and damage, but no marked extension of their range, while in Scotland the numbers and range of the Grey squirrel did not alter nor did damage occur. There has been little alteration in the general picture of the Red squirrel's abundance and distribution. In Wales the slow general decrease in numbers and contraction of range continues. In Scotland and England there have been no significant changes.

A general Mammal/Bird/Damage Questionnaire was sent out to all Forestry Commission areas in 1962 requesting information on the presence of most of the British mammals and of birds which may be responsible for damage. Information was also requested on the extent and frequency of damage caused by mammals and birds. The results are being summarised and a report is in preparation.

A deer questionnaire, requesting information on species present, numbers killed and importance of damage, has been prepared for annual issue.

The effects of the hard winter on muntjak was the subject of a special questionnaire sent to all the forests which reported the presence of these deer in the 1962 Mammal/Bird/Damage Questionnaire. The results showed that muntjak were hard hit by the conditions and estimates of mortality varied from ten per cent to seventy per cent of the population concerned. The majority of deaths resulted either from starvation or from reduced mobility in the snow, making the deer easy prey for dogs.

FOREST MANAGEMENT

By D. R. JOHNSON, D. Y. M. ROBERTSON, A. J. GRAYSON and R. T. BRADLEY

GENERAL

During the year the Management Section concentrated on the development of methods and techniques for planning. These were embodied in a number of Provisional Working Plan Technical Instructions which were issued during the year, together with new Management Tables which are in course of preparation. The new tables and the technical instructions formed the basis for a series of planning courses for Divisional and District Officers.

A hardwood pulpwood survey in Wales and the South of England was started during December, but the hard winter prevented completion of the work before the end of the year under review.

The Management Section assisted in the work of the Cabinet Working Party on Forestry Policy.

The reports for the individual sections are given below.

D.R.J.

WORKING PLANS

During the year, working plan fieldwork was completed at forests having a gross area of 163,000 acres. At the end of the year teams were operating in forests totalling 280,000 acres. This latter figure is inflated by the fact that several very large forests including Kielder were taken into the programme.

The system introduced at the end of last year of using "checkers" for making spot checks in the field, to test the accuracy of the work, has worked reasonably well. It is hoped, however, to make the system more efficient by reducing the number to three for the whole country and relieving them of any "sample plot" responsibility. In addition to field checks the "checkers" will be responsible for ensuring the uniform layout of working plan forms produced by parties in their area.

On his return from training with the Soil Survey of Great Britain, our Soil Survey Officer proceeded with the survey of the New Forest. During the work he trained an Assistant Forester who will be kept on this specialised work for some years. At the end of the year the New Forest survey was practically complete and it seems certain that the results obtained are capable of being used in arriving at Management decisions.

Two Foresters and two Assistant Foresters were given training, by the Department of Overseas Survey, in plotting from aerial photographs. This training is proving useful in Scotland where Ordnance Survey vertical photographs are available. In Wales, unfortunately, our proposed contract flying of Clocaenog Forest failed due to bad weather and the men trained have so far not been used on plotting. It is now becoming clear that, due to the large proportion of forest area accurately surveyed, and to the difficulty of obtaining photographs at the right time, the use of photographs for survey work in the Commission has only a limited future.

Liaison with the Ordnance Survey continued and fieldwork at Kershope Forest is now proceeding on revised maps produced by our draughtsmen at Southampton. Maps for Kielder are not yet available. Maps of Wareham and Coed Morgannwg are being revised with the aid of newly published Ordnance Survey 25-inch-to-one-mile sheets.

At the end of the year work on revision of the Working Plan Code was proceeding; the main effect of the amendments will be to speed up the process of sanction and to increase the liaison with specialist officers and Management Section during writing.

Also at the end of the year the fieldwork for a survey of hardwood pulpwood resources within the supply area for a pulpmill at Sudbrook near Chepstow in

Monmouthshire was being completed. This survey is being conducted on the basis of randomly sited samples and will provide useful information on techniques for any future national census.

D.R.

ECONOMICS

The research element of work in this section has been limited, while the main contribution has lain in the field of advisory work. Aids to planning relating to species choice, rotation fixing and choice of road density have been prepared, and more field experience of their application has been gained. Material on the economics of forestry was prepared for a Cabinet committee reviewing forest policy. Calculations of the relative profitability of forestry and agriculture on various types of land have been completed for the Land Use Study Group. The two main criteria adopted in this work are net discounted revenue per acre and net discounted revenue per £100 of capital, where capital is defined as the sum of items of expenditure (suitably discounted to the initial year of the project) incurred up to the time when the investment provides a positive net revenue. Interest rates of 3, 5 and 7% have been used in these calculations. As yet, constant prices only have been built into the computations, but it is clear that a good deal more work requires to be done on the likely future price development of forest and farm products, and on the inclusion of the findings into the calculations before the resulting figures can be said to have much economic significance.

A review of historical developments in wood and wood product prices conducted to date has produced some interesting findings. For softwood in major producing countries it appears that stumpage prices in real terms (i.e. after the effect of changes in the value of money has been removed) have risen at an annual rate of about 1½% compound over the past half-century. Wood products further along the processing chain show smaller increases in price. In general, higher raw material prices have been counter-balanced to a greater or lesser extent by increased efficiency of processing. The significant point arising out of the finding of an annual 1½% increase in the real price of standing timber is that, if this trend continues, then rates of return on investment based on constant prices understate the real return by 1½%. This is clearly important where the yield on forestry investment is being compared with yields of other enterprises showing no such trend in the real prices of their products.

Another important trend bearing on management of existing forest and on investment in new projects is the movement in real costs of silvicultural operations. Because of the high labour intensity of forestry, interest naturally centres on movements in labour productivity. An assessment for Forestry Commission operations over the years 1954 to 1962 indicates that real output per man-year of labour has risen at about 2½% per year on average. This is equivalent to roughly 3½% per man-hour. The method of assessment relied on a weighting of the physical output of work done by wages expenditure in a base year. The choice of base year was found to have negligible effect on the change in labour productivity determined.

Among further studies of profitable stand management, two items may be selected for their general interest. Cases of crops with low increment per acre, such as the larches, are commonly regarded as requiring special consideration by managers. The apparently low rate of exploitation of the site potential is viewed with concern, and early replacement with higher volume producing crops is often advocated. While no general survey has been undertaken, it does appear that the case for early replacement can often be over-stated. Where the value increment per acre is low but not negligible, returns to capital and to land are frequently found to vary only very slightly over quite wide ranges of retention period, and the optimum date of replacement of the lower-yielding stand may approach the rotation age which might be calculated as optimal for a succession of crops of the existing species. A useful measure of flexibility in management is thus introduced.

Another application of the criterion of profitability adopted by the Forestry Commission arises in connection with coppice management. Here the return to capital may well be found to be maximised by retaining coppice (assuming coppice working does yield a positive net discounted revenue) in circumstances where capital is limited relative to the area of coppice under consideration, and to the extent of other profitable investments. But if the coppice area is limited relative to the availability of capital for investment, then the best course may well be to convert the coppice to high forest (assuming this to yield a positive net discounted revenue also). The optimum solution of the problem whether to convert coppice to high forest or not cannot be decided however without fuller knowledge of the range of investments open, as well as of the constraints (i.e. land and capital availabilities) which are likely to apply.

A.J.G.

MENSURATION

The revision and extension of the general yield tables for conifers now forms part of the development of new Forest Management Tables which are designed to provide most of the information required for classifying rates of growth, taking into account local growth patterns, controlling and forecasting thinning yields, and planning production for even-aged coniferous plantations. The tables will, in the first place, be prepared for pure crops of Scots and Corsican pines, Sitka and Norway spruces, and for Douglas fir, but general stand/assortment tables will be incorporated which can be used to determine the breakdown of numbers of trees and of volume by breast-height quarter-girth classes and the proportion of the volume to various top diameter limits for all conifers, given the mean girth of the crop or of the thinnings.

The Forest Management tables are based upon a new system for classifying rate of growth which is based upon maximum mean annual volume increment. Intervals of 20 hoppus feet separate the Yield Classes which are numbered, independently of species, according to the maximum mean annual increment which they represent, e.g. Yield Class 200 means that the site/species combination has a potential max. m.a.i. of 200 h. ft. per acre per annum at some (unspecified) age. Although the Yield Classes are based upon volume production, top height will still be used as the method of identifying the appropriate class, and top height/age curves will be used for this purpose.

The Yield Class rating derived by a consideration of height and age can be modified to take account of local growth differences by determining the Production Class for the stand or group of stands. There will be three Production Classes 'a', 'b' and 'c' which represent higher-than-average, average, and lower-than-average volume production for a given top height. If Production Class is found to be 'a', the Yield Class rating is moved up one, e.g. from Y.C. 200 to Y.C. 220, if 'c' down one to Y.C. 180. Total volume or basal area production or the mean girth of the 40 largest-girthed trees per acre will be used as indices of Production Class in conjunction with top height rather than age.

The yield tables will show the development of crops in the various Yield Classes all consistently thinned from the normal time of first thinning, such as to maintain the greatest girth increment which is compatible with maximum volume increment per unit area. This can, in general and in the long term, be regarded as the optimum pattern of thinning from the economic point of view without having to invoke assumptions of doubtful validity. Local market conditions may result in a slightly different optimum, but by expressing the intensity of thinning in terms of annual thinning yield, such local considerations can be taken into account by varying the thinning cycle and hence the volume removed in a particular thinning. Furthermore, since an intermediate type of thinning is assumed in the tables and since type of thinning does not have a great effect on the critical intensity, the type of thinning may be used as a further factor for exploiting local marketing conditions.

In the thinning control and forecasting tables, the annual thinning yield is assumed to be independent of the level of stocking, since this greatly simplifies matters without being mensurationally any less acceptable than control by means of the level of the growing stock. It is, however, intended that the yield represented by suppressed trees in an overstocked stand should be removed where a market is available or where desirable on pathological grounds, in addition to the tabulated yield. The control tables show the annual thinning yield in terms of basal area to facilitate checking at the marking stage, using a relascope or small sample plots.

The encoding of permanent sample plot summary onto paper tape for computer work is progressing steadily and a start has been made in writing programmes and encoding single tree information for the investigation of the growth of different components of the crop. This work is being carried out concurrently with the production, by graphical methods, of the Forest Management Tables. It is hoped that most of the data processing will soon be carried out by electronic computer but the development of techniques is still in the exploratory stage.

A new series of experiments using transplants has been started to test the effects of spacing and thinning within the span of one growing season, in the hope that the technique may provide information of some value in predicting the reaction of stands during their normal life cycle.

R.T.B.

WORK STUDY

By J. W. L. ZEHETMAYR

The assignments started last year continued throughout the Forest Year but two new ones were begun early in 1963; details of the main subjects studied are set out overleaf:—

List of Assignments with Planned Dates

Conservancy and Forests	*Dates*	*Main Subjects of study*
North East England (Border District) Kielder Redesdale Wark	Oct. 1960– Dec. 1962	Brashing Drain maintenance and layout Pulpwood working Machinery trials
North Wales Main work at: Mathrafal Dyfnant Kerry	Jan. 1961– July 1963	Brashing and pruning Weeding, cleaning and clearing Drain maintenance Pulpwood working
North Scotland South Strome	Apl. 1961– (1964)	Scottish pulp:— Specification Production in forest Loading and transport
East England Thetford Chase Brandon Depot	Sept. 1960– (1964)	Work complete on main operations as at present organised. Now investigating:— (a) Mechanisation of pit prop production (b) Supply to Novobord sawmill and boardmill.
North West England Thornthwaite	Aug. 1962	Production operations
New Forest	Jan. 1963	General assignment on Forest maintenance operations and Production operations.

The assignments are of varied type; that at South Strome continues to investigate production methods for a particular end point—the pulpmill at Fort William. In contrast, the production assignment at Thetford has, until recently, concerned itself with the extensive operations now proceeding, and has only recently turned towards future major developments. The assignments on forest maintenance have been extensive, into many beats and forests, rather than intensive.

During the year a considerable number of trials were in progress on machines which are in production or in an advanced stage of development, and which need detailed work and prolonged trials in order to assess their suitability under normal forest working conditions. This work, while partly carried out by the field teams, has been co-ordinated by the District Officer stationed in Edinburgh.

The stage reached in the various operations under study is as follows:

SILVICULTURAL OPERATIONS

Weeding, Cleaning, and Clearing for Planting

The initial work was carried out at Mathrafal, North Wales, under a wide variety of conditions in the summer and winter of 1961. Hand tools employed have been reviewed so that foresters can be given guidance on the best specification and manufacturer for any particular job. This work, which will entail revision of the Forestry Commission Tool List, is nearing completion.

In addition, portable powered brushcutters were compared with hand tools, the general finding being that, while valuable for clearing work, they can only reduce costs in weeding under particular circumstances, such as dense woody regrowth.

From the work in the 1961 season also emerged a draft piecework scheme which was tested in six forests in the summer of 1962. After revision in the light of experience the standard times are assessed on the following factors:—

(a) Hand tools or machine work
(b) A broad classification of vegetation types: (A.) Bracken, herbaceous plants, and soft grasses. (B.) Coarse grasses and rushes. (C.) Woody weeds and climbers
(c) Assessment of proportion and density of woody growth
(d) Spacing of the plants
(e) Other factors, e.g. visibility of plants, two season's growth of weeds, steepness of slopes.

Times per square chain range between 40 and 120 standard minutes according to conditions. The assessment is of necessity subjective but appears to work satisfactorily in practice.

Foresters were left free to decide whether the rates actually paid were their own or those indicated by the tables of standard times, but in either case the vegetation was assessed and performance recorded for each block weeded. All the supervisors concerned were instructed in the details of the scheme and visited as the season progressed. The results of the second year's work are now being worked up.

Brashing

Studies carried out in spruce in 1960/61 were worked into a provisional piece rate scheme. Brashing time for a tree was found to depend mainly on the coarseness of the branches defined in terms of their thickness and toughness, and to a lesser extent on the number of whorls. Generally it was found that brashing about 800-1,000 trees per acre gave good access, regardless of the initial stocking.

The brashing piece rate and costing scheme devised is on the following lines:—

(a) Assessment of a coarseness index for the stand.
(b) Payment by the number of trees—usually a price per 100 trees is convenient.
(c) Record of numbers brashed in the stand.
(d) Control by the acreage.

If desired the rates can be converted to a price per acre with control by check of numbers brashed per unit area, but this is not recommended for general use. The testing of this scheme has been completed in some fifty stands in the Border Forests and North Wales, covering 1,200 man days work. Output varied inversely with coarseness from 400 to 150 trees per man-day. The range of earnings shows no correlation with coarseness or with rates paid, but a fairly even spread around a reasonable mean figure. In view of the number of men and forests involved this is regarded as proof of the soundness of the standard times and rates derived from them.

Pruning

The first studies on pruning were made on Norway spruce at Dyfnant, North Wales. Work started on tools—various saws and poles being compared. A 20 in. saw, with 7 ft. sectional rods, made up by Conservator, East England was considered the best of those considered.

Pruning was carried out to a number of heights, and it is possible to relate the costs to that of brashing in a particular stand.

The relative times for pruning successive 6 ft. lengths were as follows:—

Job	*Pole used*	*Relative times*
Brash 0 – 6 ft.	—	1
Prune 6 –12 ,,	7 ft.	1¼
Prune 12–18 ,,	14 ft.	2
Prune 18–24 ,,	21 ft.	2½

Thus to prune the upper 12 feet takes twice as long as the lower 12 feet. The relative values are likely to hold good over a wider range than the actual times obtained in the stands concerned.

Drain Maintenance

A considerable amount of time study has been carried out at Kielder, and latterly at Dyfnant, on hand cleaning with rutter, hack and spade. As far as methods are concerned little improvement can be proposed apart from the use of a case-hardened rutter—small supplies of which are now on trial in Conservancies. Provisional tables of standard time based on the amount of deepening and widening to be achieved are under trial in both North Wales and North East England.

In trials of machines for drain cleaning, a drain cleaner, working on the flail principle, proved quite unable to endure more than a few hours running: the Melio is on long-term tests (see report below).

It appears that the ultimate solution of this problem does not lie along the lines of seeking to clean and deepen the extensive drain system resulting from ploughing and turfing for planting. Liaison has been maintained with the Silviculture and Soils Sections in their enquiry into drain layout and design. With suitable machinery the aim should be deeper, self-cleaning drains, and drain cleaning, as seen today, should disappear in the course of time. Drain cleaning by hand will be necessary over many thousands of acres in the next two or three decades, and the greatest possibilities of saving lie with supervisors in carefully choosing which drains are to be maintained and deepened to form the permanent system.

PRODUCTION OPERATIONS

General

The year has seen a considerable step forward in rationalising the work of felling, extraction, and conversion, by finding the methods and equipment which will minimise costs to the forest industry as a whole. It appears that practice is shaping itself on the following lines:—

(a) A minimum of conversion will take place at stump by well-trained fellers who will also place billets, but not logs, ready for extraction.

(b) Extraction will be integrated with felling, e.g. by using fellers as chokermen for winches, or as in team working.
(c) The introduction of mechanical loading on to transport means that billets must be of reasonable size, or be handled in bulk (or both).
(d) Major conversion work, especially peeling, must be undertaken in 'factory conditions' at conversion depot or mill's woodyard.

While it is by no means possible to implement the above on all sites or for all products today, there are examples—Thetford Chase is one—where it is almost fulfilled. The development work on pulpwood has shown how far it can be achieved even in difficult conditions, provided that the end product is known. Extraction remains the crux of any logging operation but three new developments seem likely to make valuable contributions, i.e.:— (a) Scandinavian harness and horse equipment to increase loads; (b) Tractor-mounted double drum winches; (c) Light tracked tractors, with winch and sledge.

The two latter machines are described in more detail below.

To work with any of these equipments much more detailed planning of operations is required, particularly to allow access to plantations and to give adequate working space at roadside.

Pulpwood for Fort William (Team at Strome, North Scotland)

In the first half of the year a series of trials was undertaken to test various possible specifications of pulpwood for the Scottish Pulp and Paper Mills of Wiggins Teape & Co., Ltd. The main task was to determine the most efficient length to which pulpwood should be cut. In the broadest sense this means the "cheapest up to the chippers" and it covers, therefore, such considerations as:—

(a) The most efficient length for extraction—Scandinavian practice favours lengths of 9 to 15 ft., whereas we are accustomed to pole lengths.
(b) Crosscutting in the wood as opposed to roadside.
(c) Loading and transport—the haulage distances are very long and the greatest possible load must be carried coupled with a quick turn round.
(d) The optimum length for handling and peeling at the mill, with consideration of tolerance and waste.

Both a theoretical, and a practical approach was made to these problems and the following results were obtained;—

(i) A trial showed that crosscutting in the wood to 10–15 ft. and extraction by specialised horse equipment was at least as efficient as dragging pole lengths and crosscutting at roadside.
(ii) Calculations on transport costs were made based on the *Commercial Motor's* Tables of operating costs and time study data on loading times for various lorries, timber specifications and lorry-mounted cranes. The results show the advantages over long distances of using a shuttle system, by which one tug carrying the crane loads trailers in the forest and puts them on the main road, while other tugs without cranes take them to the mill. Calculations have also covered load and wheel disposition to give the largest load, maximum stability, and maximum traction, while keeping within the legal limits.

These findings have been followed in putting into practice a system of working pulpwood by various methods with recorded outputs. The results, which are summarised below, refer to spruce of 3–5 Hoppus ft. per tree.

	Output in hoppus feet
Felling, snedding, crosscutting logs and 10–12 ft. pulpwood lengths—piling the latter for extraction	100–150 per man-day
Extraction with Swedish horse sledges*	180–220 „ „ „
Extraction with Isachsen winch ..	300–600 per team-day
Loading 12 tons with HIAB Elefant crane by one man	1½–2 hours

These outputs have been accomplished with a mixture of piecework and bonus working, and while there is some difficulty in costing pioneer equipment, it is thought that overall costs will be low.

Thetford Chase

The year opened with a review based on time studies of all operations in Thetford Chase and at the Brandon depot, together with an analysis of the cost of each specification prepared in the woods and its processing through the depot on to transport. This analysis showed that:

(a) The total costs (including overheads) to depot were doubled as between unpeeled 6½ ft. butts and peeled poles of 1½ hoppus ft. average volume.

(b) There is a big range in surplus from the different production lines: small poles, giving a high proportion of stakes, are as profitable as logs, while poles with a poor stake output are only half as valuable.

(c) Pitprop production by present methods cannot give low peeling costs and low transport costs, when the majority of props are cut to order.

(d) The average pole worked at Thetford is still only 2¼ hoppus ft.

Action has been taken to increase the production of high-value material—stakes, props, and woodwool. In addition, the various alternatives for mechanising pit prop production has been investigated to give reduced costs and to maintain the quality of product and service which Thetford has established. The first step will be to install a mobile Cambio peeler in the depot, primarily to peel pitwood lengths for subsequent crosscutting after seasoning.

Groundwood Pulpwood, Team working

The system of producing groundwood pulpwood with a small team complete with chain saw, horse, and sawbench has been adopted in the forests on either side of the Scottish border, following the original studies in North Wales. The specification concerned is: 4 ft. long, with tolerance to 3 ft. 7 ins., minimum tip 3½ in; maximum butt, 12 in. Records are available from five teams of four men working in Newcastleton and Forest of Ae (South Scotland) and in Kielder (North East England). They show remarkable agreement in terms of output from spruce stands of about 2–3 hoppus ft. average, which was 60–70 hoppus ft. per man-day loaded on lorry. This is equivalent to a potential output of over 50,000 hoppus ft. per 4-man-team year comprising:—1,200 tons groundwood pulpwood (37,000 hoppus ft.), and 12,000 hoppus ft. other produce—logs, stakes, boardmill, etc.

Although only one team achieved this output in the year, this was because the other teams were on other work part of the year to balance production with their delivery quotas.

* See Plate 9, central inset.

STANDARD TIMES AND CONTROL PROCEDURES

Standard Time Studies

No new schemes were prepared during the year but the following additions were made to existing ones:—

(a) *North Wales*

Weeding—a provisional and final scheme
Brashing spruce—a final scheme to replace the provisional
Pruning—provisional for Norway spruce
Drains maintenance—provisional
Crosscutting of groundwood pulpwood—a revised scheme based on the use of chain saws to produce 'maximum pulpwood' or 'maximum logs'.
Thinning of Sitka spruce—an extension of the range to larger trees

(b) *Borders District, North East England*

Horse dragging – final
Lorry loading of pulpwood – „
Brashing of spruce – „
Drain maintenance – „

(c) *Thetford and Brandon*

Though not set out in the form of a booklet all the Thetford Standard Times were collated and summarised:

Forest work: Thinning pine with primary conversion and hand extraction
Hand Peeling

Depot work: Crosscutting pitwood, pulpwood and boardmill (this involves several hundred Standard Times).
Peeling pitprops
Hand loading of lorries with pulpwood, pitwood, etc.

In addition schemes were in an advanced stage of preparation for tractor extraction and lorry haulage from forest to depot

(d) The relatively small amount of study carried out in felling in North Scotland appears to confirm the soundness of the Cowal Standard Times.

Labour Control

Some considerable progress has been made, in that several Conservancies have undertaken large scale trials. Districts which have operated the scheme for one or two years find it invaluable for improving management and in providing data for negotiations on piece rates.

FOREST TRIALS OF MACHINES

Drain Cleaning Machines

The only machine given actual field trials was the "Melio". In certain conditions, its performance gives costs similar to those for hand cleaning, it is however, only suitable for drain deepening on peat or stone-free soil where there is sufficient room between trees for a suitable tractor to pass. The intended long-term trial was badly interrupted by mechanical difficulties—the need to alter the gear ratio of the tractor and to recondition the helical drain cleaner. All other machines suitable for drain cleaning *in the forest* are at the stage of mechanical development rather than of field trial.

Brushcutters

Work with the small portable one-man brushcutters on weeding has been extended to cover preparation of ground for planting. The conclusions reached are:—

(a) These machines save time on weed growths such as herbs, bramble and light coppice, but the time saved is not enough to cover the operating costs of the machine and there are no financial savings, as compared with hand work.

(b) On dense woody growths such as gorse, blackthorn or ash coppice considerable reductions in costs are achieved compared with hand work.

(c) A minimum of 400 hours in use per machine per year is necessary to bring operating costs per hour down to a reasonable level.

Chain Saw Operating Enquiry

The scheme to obtain figures of usage, costs and details of repairs from workers owning saws was commenced at the beginning of the year; of twenty men who started, ten have sent in complete data. Though this is not as many as had been hoped, some useful information will be obtained. It is proposed to continue the enquiry for a further year.

Isachsen Double Drum Winch

Forest trials of the large No. 3 model have continued throughout the year with some good results. In windblow (and by inference, in clear falls), on ground where wheeled tractors cannot operate, the double drum winch has proved itself to be cheaper than horse work. In thinnings, when extracting tree lengths, it was not cheaper; but further trials with racks at twenty yards apart, crosscutting at stump and preparation of loads by the fellers, coupled with training by an experienced Norwegian operator, have proved the machine capable of lower costs than horse extraction by dragging along the ground. The comparison with improved horse extraction using Scandinavian sledge equipment has now to be made, and a direct comparison with the Boughton hydraulic double drum winch is to be undertaken.

The Isachsen has proved itself as an effective and economic extraction method for certain conditions, but training of operators is essential and, in thinnings, rack layout and preparation of loads are vital factors.

See also Plates 10 and 11, central inset.

Light Tracked Tractor

A Ferguson tractor has been fitted with a standard Norwegian conversion by locking the front wheels, adding a pair of idlers and light metal tracks. To this tractor has been fitted the small Isachsen double drum winch (No. 1) and also a Jo-Bu sledge mounted on the three point linkage. Thus three separate equipment trials are being made with the one machine.

The success of the tracks in enabling the tractor to get into the stands has been such that it is now clear that a double drum winch is not required in the Borders, and it has mainly worked with one drum. Initial troubles were experienced with the steering brakes and the locking of the front wheels. The sledge allows the tractor to manoeuvre 'light', by raising the linkage to turn or to back up a rack. The bolster has been re-designed to allow for quick release of the load.

The method of working would be for the tractor operating in racks to serve a number of fellers, winching from the stand on to sledge and moving loads of 20–30 hoppus ft. to conversion point on roadside. This development is the first which appears to offer an alternative to the horse on typical Border country of gentle slopes but soft peat.

Hiab Elefant, Hydraulic Grab and 12-ton Articulated Lorry (Plate 12)

This equipment is being operated to obtain figures on loading and haulage for the Scottish Pulp specification under Highland road and traffic conditions. As now modified, the HIAB Elefant, with a reach of 21 ft. and with the controls on the top of the cab so that the driver can have a clear view of the whole loading operation, enables one man to load 10-foot lengths of pulpwood.

Two patterns of bolsters with quick release pins have been imported from Sweden for use with this vehicle and these have already shown themselves superior to the type normally used in this country. The release of pins from the *opposite* side of the lorry is an important safety factor.

Operating experience over six months shows that reasonable speeds can be maintained except on unimproved single track roads. Tourist traffic in the summer has not been the handicap expected and tends only to be dense at peak periods of the day; performance under winter conditions will be assessed later.

DISSEMINATION OF INFORMATION

Reports

Four quarterly reports with seven appended papers reporting on particular studies or developments, have been produced during the year for internal circulation within the Forestry Commission.

Some twenty reports were made to Conservators during the normal course of assignments, some of them being extensively distributed locally, e.g. down to Forester level over a Division or Conservancy. These form the basis for some of the more widely circulated reports and publications.

Courses and Talks

Three one-week courses on Work Study were held at Northerwood House, while lectures on Method Study and Time Study were given at three of the Scottish Woodland Owners Association's series of three-day courses. Talks and demonstrations, either separately or forming part of wider based courses, were given at five other courses, to three forestry schools and universities and at an excursion of the Royal Forestry Society of England, Wales and Northern Ireland.

Open Weeks at Inverliever and South Strome

The working of the double drum winch was demonstrated in windblow at Inverliever to timber merchants and contractors during a week in March 1962. Representatives of six firms, two contractors, and Scottish Woodland Owners Association attended—a total of fifteen people. This new venture in demonstration was considered to have been very successful since there was only one item of equipment in a remote part of the country. It was followed up with a much more extensive demonstration of logging methods at South Strome Forest in October 1962. The object was to allow close examination of actual operations and discussion of methods by those intimately concerned rather than with the general forestry public. Almost one hundred people attended during this week.

Machinery Demonstration at Bush House, Edinburgh—June 1962

The Work Study Section contributed a substantial share of the large Forestry Commission exhibit at this show. The Section's exhibit consisted of a display of tools, maintenance equipment, and machinery—either recommended already for widespread use in the Commission, or under trial at the present time and considered promising.

UTILISATION DEVELOPMENT

By B. W. HOLTAM

Properties of Home-grown Timber

The comprehensive programme of study of the properties of home-grown timber was continued. This work was started in 1959 as a joint undertaking with the Forest Products Research Laboratory of the Department of Industrial and Scientific Research at Princes Risborough.

Work on the comparison of timber from different provenances of Lodgepole pine (*Pinus contorta*) was extended to include an assessment of pulping properties, and was concluded. The examination of the properties of Japanese larch (*Larix leptolepis*) and its comparison with the properties of European larch (*Larix decidua*) was almost completed.

Sampling of Norway spruce (*Picea abies*), from five different regions of Britain, for a full investigation of the properties of this species, was well advanced by the end of the year under review.

The selection of sample stems to compare the properties of timber from pruned and unpruned stems of Douglas fir (*Pseudotsuga taxifolia*), Norway spruce and European larch from experimental plots in the Forest of Dean was completed.

Other testing at the Laboratory included work on Grand fir (*Abies grandis*) and Noble fir (*Abies procera*). A consignment of Red oak (*Quercus borealis*) from Hampshire was also examined; this sample was found to have superior strength properties to the averages recorded for English oak (*Quercus robur* and *Quercus petraea*) and, although less durable, it seasoned with slightly less shrinkage; changes in its moisture content were accompanied by less movement than is experienced with English oak. The red oak was also easier to treat satisfactorily with preservatives.

Accelerated Air Drying of Home-grown Timber

Experiments were undertaken at the Forest Products Research Laboratory on the accelerated air drying of two-inch thick planks of home-grown Scots pine. Stacks of green timber, under a simple roof of timber framing and polythene sheeting, overhanging the timber by about two feet, were subjected to a continuous flow of air from large fans, during the winter months. The time taken to dry the timber to a moisture content of 30% of the oven dry weight was almost half of that required by the control stacks, which were roofed over, but not fanned.

A similar project in which pitprops were dried at an accelerated rate in a current of warm air in an air-tunnel showed that props dried in this way developed the high strength associated with props seasoned by normal methods.

Sawn Hardwoods

Visits were made to furniture manufacturers, flooring contractors, wood turners and civil engineering consultants, to obtain information on requirements, specifications and trends. Further visits are being undertaken.

An assessment of the yield of merchantable sawn timber obtainable from typical low quality English oak boles in the Forest of Dean was started.

Six trees were selected at random from "Worcester Walk" and "Russells Inclosure". They were sawn through-and-through into one-inch boards at a local sawmill and dispatched to the Forest Products Research Laboratory. At the Laboratory the sawn oak was examined, and the location of defects and the extent of the sapwood were recorded on drawings. The work is continuing.

Wood Flakes as Litter for Cattle and Poultry

The work mentioned in the previous year's report has been continued. A machine was designed, in collaboration with the Forest Products Research Laboratory and the National Agricultural Advisory Service of the Ministry of Agriculture, Fisheries and Food, for the conversion of small round timber and slabwood into wood flakes suitable for use as animal litter. The machine was then further developed by a firm of engineers, who are now marketing models which may be driven from the power take-off of a tractor, or belt driven from an electric motor.

A number of trials have been set up to make observations on the litter in use. At the National Agricultural Advisory Service's experimental husbandry farm at Trawscoed in Cardiganshire six beef cattle were bedded on about 3 tons of dry flakes in an area of approximately 420 square feet, for eight weeks. The litter was retained for application as manure to a hay crop where it is being compared with other forms of farmyard manure. At Penglais Farm, University College of Wales, Aberystwyth, a dairy herd was kept on deep litter of wood flakes for a few weeks, and a comparison is being made between the service given by sawdust, straw and wood flakes, used as bedding in a conventional cowshed. At the National Institute for Research in Dairying at Reading, wood flakes are being used on the litter area of the covered yard, which houses a dairy herd; at this site daily observations on the cleanliness of the cattle are being recorded. At one of Reading University farms a small quantity of flakes was used as poultry litter.

Similar trials have been made with beef cattle and with poultry at the Bush

Farm of the Edinburgh and East of Scotland College of Agriculture, in Midlothian.

While the trials have shown that the flakes are suitable for use as litter, full results are not yet available on their service and cost compared with straw, nor on the comparative suitability of "wood flake manure".

MACHINERY RESEARCH

By R. G. SHAW

The year under review included the third Forest Machinery Exhibition which was held at Edinburgh on the 5th and 6th of June 1962. This was the largest and best attended of this series of exhibitions and attracted overseas visitors from Spain, India, Pakistan, Czechoslovakia, West Germany, Italy, France, Poland, U.S.S.R. Many of the machines used in forestry are either standard products of the British agricultural engineering industry or closely related designs. Specialist machinery is designed and manufactured where no agricultural equivalent exists. Hydraulic power transmission is making progress through its adoption on many of these specialist machines but it is only slowly appearing on machinery in large scale production due to the present price difference. The situation on specific machinery development projects is as follows:—

Forest Tractors

The tractors used in the forest are basically agricultural models and the general improvement in design, including the higher power outputs from tractors of similar size to their predecessors, are very welcome features. The greater power available at the power take-off is of particular importance in view of the many operations now carried out by auxiliary equipment driven by the power take-off.

Engine Starter

Engine starting particularly in cold weather on tractors and transport vehicles standing in the open has, in the past, caused great delay and loss of production. A small petrol driven generator weighing only 40 lbs. has recently been developed and initial trials indicate that a tractor, on which the battery fails to turn over the engine, can be started quite easily after 90 seconds charging with this unit. Extended tests including cold room starts at sub-zero temperatures are being undertaken.

Timber Transport

The transport of timber both from the stump and by road or rail plays a vital part in the economics of utilisation. The problem is one calling for both improved machinery and studies of the best methods of applying it. Work Study is, therefore, closely allied with machinery development in this field. The steep gradient of the hillsides on which a great deal of the timber is growing means that the initial haul from the stump to road vehicles produces expensive volume/distance figures. At present the double drum winch is the most promising project under development for this initial haul. (See Plates 10 and 11, central inset).

Loading Devices

Loading onto road vehicles carrying increasing payloads calls for more and more mechanisation. At present, two imported loaders the Hiab (Plate 12, central inset) and the Tico are widely used for this operation. Various forms of pallet loading are under review but none is yet in use.

Ploughs

Ploughing continues to be carried out with various forms of the tine plough on heathland areas and the Cuthbertson drainage ploughs on peat. There is an increasing need to provide deeper cultivation on the harder compacted ground to improve root penetration to resist windblow. The heavy drawbar pulls involved lead to higher tractor costs so the possibilities of vibrating tines to achieve deep disruption with reduced drawbar pull are being investigated.

Drain Clearing

This is still an expensive operation in both cash and physical effort. The Croucher machine, consisting of a power driven endless chain cutter operated by two men walking on the drain bottom has been produced during the year.

A requirement now exists for a machine that will deepen drains to 24 inches whilst cleaning. Further development to achieve this target is being undertaken.

Bark Peeling

This is required on an increasing scale. A satisfactory solution for peeling in large quantities has been found to be the Swedish Cambio machine of which there are a number now in Britain. A portable unit for pit prop peeling will shortly be in use at the Forestry Commission depot at Brandon, Suffolk.

Sawbenches

A light sawbench based on the pendulum principle, and particularly suitable for the smaller woodland owner, is being imported from France for trials.

DESIGN AND ANALYSIS OF EXPERIMENTS

By J. N. R. JEFFERS

The major event of the year, from the point of view of the Statistics Section, has been the installation of a Ferranti Sirius computer at the Forestry Commission Research Station at Alice Holt. Although this machine only came into operation on the 1st March, 1963, much of the work of the Section over the past year has been concerned with the necessary preparatory work involved in the choice of the particular computer to be installed, the re-planning of the structure and organisation of the Section to make the best use of the machine, and the training of the staff of the Section, and of research officers in other Sections, in computer programming and techniques.

Details of the Ferranti Sirius computer, and of its advantages in forest research and management, were given in Part III of the *Research Report* for 1962.

Before the installation of the Forestry Commission's own machine, extensive use was made of the electronic digital computers of other organisations. In particular, the Ferranti Pegasus computer at the Royal Aircraft Establishment, Farnborough, was used to process the bulk of the experimental data collected by the Research Branch. The Sirius computers at the Battersea College of Technology, London University and at the Heriot-Watt College, Edinburgh University, were also made use of to a considerable extent.

There has been no change, in the year under review, in the numbers of staff in the Section, or in the proportion of qualified statisticians to machine operators.

The work of the Section has continued to be,

(a) To provide advice on the design and analysis of investigations in forest research and management.

(b) To analyse and interpret numerical information for other Sections of the Research Branch and of the Forestry Commission in general.

(c) To undertake research into the application of statistical methods and methods of electronic computing to forest research and management.

While priority has continued to be given to the first of these functions, the importance of the third function, that of research into the application of new methods, and particularly those of electronic computing, has increased, and has been given correspondingly more time.

Design of Experiments and Surveys

Designs have been provided for more than 100 investigations throughout the year. No very marked change in the types of designs required or the subjects under investigation has been observed, except for a slight increase in the number of sample surveys on topics of interest to forestry management. The latter have included a survey of the age and length of service of industrial workers in the Forestry Commission (see page 172), a survey of the loss of time through sickness and absenteeism in Commission forests, and a survey of the volumes of hardwood timber within given distances of the Sudbrook pulp mill.

The compilation of data for the *Handbook of Research Planning-Factor Data* of the United States Department of Agriculture has been continued.

Analysis of Experiments and Surveys

Despite the time spent in the transfer of the main bulk of the computing from a Pegasus computer to a Sirius computer, more than 10,000 separate analyses were completed during the year. About one-third of these analyses were routine analyses of intermediate assessments of experiments, one-third were more complex analyses of experiments considered jointly, while the remainder were analyses and tabulations of surveys and other investigations.

Further work has been done on the application of methods of multivariate analysis to problems of forestry research and management, and, in particular on the application of principal component analysis. Intensive studies of methods of operational research have also been carried out, with the intention of extending the scope of the work of the Statistics Section in this direction.

International Union of Forest Research Organisations

Work in connection with the Advisory Group of Forest Statisticians of Section 25 of the International Union of Forest Research Organisations has continued, the special responsibility of the Statistician at Alice Holt being the collection and distribution of information on electronic digital computers and their application to problems of forestry research.

PHOTOGRAPHY

By I. A. ANDERSON

Photographic Collection

14,180 slides were loaned in the period—some 800 less than in the previous year. This was not as large a drop as we had anticipated, in view of the fact that the production of standard sets is proceeding. It is to be hoped that, when this work is completed, we shall see an appreciable reduction in the demands made on the Central Collection.

There are now some 30,000 photographs in the Collection, and we are beginning to encounter storage difficulties. Some "weeding" of out-dated material is obviously necessary, and a start will be made on this during the forthcoming winter.

Requests from outside agencies for the use of our photographs, and demands for exhibition and display material, are increasing.

Films

338 loans of films were made. Considering that many of these are of considerable age, the continuing and increasing use being made of them gives a clear indication of the demand for this particular medium. To meet this, it is proposed to start a modest film programme. Initially, this will consist of no more than short record or training films, until scripts can be prepared for the longer documentary productions already agreed.

General Services

These continue much as before. No extension has been made to the facilities available, but more time is now being taken up by advisory work, document and plan copying, and map reproduction.

Illustration

The gradual introduction of new "aids" such as Letraset, Chart-Pak, and Plastitone, has led to a steady improvement in the presentation of diagrams, graphs, plans, etc. It is now possible to give consideration to some form of standardization in the preparation of these items within Research Branch.

PART II

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

RESEARCH ON SCOTTISH FOREST AND NURSERY SOILS

By W. O. BINNS and J. KEAY,

The Macaulay Institute for Soil Research, Aberdeen

The work has continued on the same broad lines as last year, with an increasing emphasis towards tree growth on peat. The problem of aeration in peat is now under investigation.

Fertility of Sand Dunes

The series of experiments at Culbin has shown that the growth rate of young Corsican pine trees can be doubled by the application of 'Nitrochalk'. Analysis of foliage from the experiment testing rates and frequency of application of nitrogen indicates that the optimum concentration of nitrogen in the foliage is much lower than that found optimum for Scots pine in Scandinavia. Whether this is a result of the dry conditions which prevail on the sand, or whether the requirements of the two species are different, is a question which only further investigation can answer.

That the primary mineral deficiency is of nitrogen is shown in the nutrient deficiency demonstration where the plots receiving all nutrients except nitrogen are indistinguishable from the control plots. In the presence of nitrogen it appears that the next deficiency is of potassium. The concentration of potassium in foliage from one of the plots receiving all nutrients except potassium has fallen to 0.43% and the needles of a few trees have developed yellow tips.

The symptoms of sulphur deficiency observed in 1961 did not appear in 1962, nor was there a height response to added sulphur. The girth increment has not yet been examined. Culture work has been continued to examine the sulphur content of foliage in sulphur deficient seedlings.

Soil Aeration and the Oxygen Requirements of Trees

A polarographic method for estimating the rate of diffusion of oxygen through soils has been tested. This method, developed in the U.S.A., has been used in ecological work in this country. It is not a precise method, and has several disadvantages for experimental work.

A more recently developed membrane-covered electrode has been preferred and promises to be of more general value.

A field experiment at Inchnacardoch Forest has been set up in collaboration with the Forestry Commission Research Branch and the Peat Ecology Section of the Macaulay Institute. In this experiment on peat, water tables are being held constant at five depths from the surface to eighteen inches below the surface. The physical conditions existing in each plot and the root development of young Lodgepole pine will be examined. This attempt to study the physical conditions limiting root development of trees in peat is related to the need for more knowledge about the type and amount of drainage required to produce stable trees on peat. In particular it is hoped that the investigation will reveal how close roots will approach a constant water table in peat.

Survey of Deep Peat Areas for Afforestation

Analysis of peat samples from three Forestry Commission trial forests in Caithness and Sutherland is nearly complete. The hope is that a comparison with peatland plantations already analysed will make it possible to advise on choice of species and need for fertilizers.

Nutrition of Mature Stands

In the last few years marked and economic increases in volume of old Scots pine and Norway spruce as a result of nitrogen fertilization have been reported from Scandinavia and Central Europe. At the suggestion of the Conservator of Forests for East Scotland a fertilizer trial was laid down in 1960 on 77-year-old Scots pine in Alltcailleach Forest, Aberdeenshire; the stand had a mean height of about 53 feet, a standing volume of about 3,500 hoppus ft. per acre, and a periodic annual increment of about 63 hoppus ft. per acre over the previous eight years.

Foliage analysis suggested that nitrogen and phosphorus were the major elements most likely to be limiting growth, so 61 lb. N and 58 lb. P per acre were applied, factorially, as 'Nitrochalk' and triple superphosphate respectively.

Increment cores taken after three growing seasons show that the NP treatment has been the most effective, and in the third year increased basal area increment by 38% and sectional area increment at 32 feet by 45%, though only the latter was significantly greater than the control. The Scandinavian work suggests that for maintaining even growth repeated dressings of N are needed every three or four years, i.e. at about the interval of "needle change"; the nitrogen content of 1962 needles is about the same in all treatments, confirming this suggestion, so the nitrogen treatments have been reapplied. An extension to this experiment has been laid down testing four rates of nitrogen applied as urea in the presence of a basal dressing of triple superphosphate.

PATHOLOGY EXPERIMENTS ON SITKA SPRUCE SEEDLINGS

By G. A. SALT

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Seed and soil treatments were used to increase growth of Sitka spruce (*Picea sitchensis*), and to raise the numbers of acceptable seedlings from a given amount of seed, on five different nursery soils. The number of seedlings obtained from

1,800 viable seed sown per square yard differed greatly between sites, although all were sown under good soil conditions in mid-March. Results appear in Table 10.

Table 10

FINAL STAND: SEEDLINGS PER SQ. YARD

Site	Kennington Old (K.90.)		Kennington Ext. (KE.88.)		Bagley Wood (B.52.)		Ringwood (R.87.)		Wareham (W.95.)	
Seed Treatment:	—	Mercury	—	Mercury	—	Mercury	—	Mercury	—	Mercury
Soil Treatment:										
Untreated	346	422	745	914	1,083	1,207	815	860	1,360	1,474
Formalin:	521	436	812	953	1,094	1,256	1,211	1,267	1,364	1,399
Chloropicrin:	578	508	725	929	781	927	1,202	1,418	1,447	1,467

Seed treatment with methoxyethyl mercury chloride was followed by higher numbers of acceptable seedlings, as compared with controls, on both untreated and treated soils, except at Kennington Old and Wareham where it was beneficial only on untreated soil. Seed treatment had no effect on seedling height, which ranged from an average of 1.23 inches in untreated soil at Ringwood, to 2.41 inches at Wareham. By contrast, soil treatments increased heights substantially at all nurseries except Wareham, where seedlings grew well without treatment, and they led to higher numbers at Kennington Old and Ringwood. Soil and seed treatments together produced the best results by combining increases in numbers and heights, but at Kennington Old losses were severe and more than two-thirds of the viable seed sown failed to emerge despite soil treatments which resulted in 37% more seedlings than untreated controls. In other experiments at Kennington Old and Ringwood, seed treatment with 50% Thiram was combined with a wider range of soil treatments. See Table 11.

Table 11

EFFECT OF SOIL TREATMENTS ON NUMBERS AND HEIGHTS

	Untreated	Formalin	Metham Sodium	Mylone	PCNB	Maneb
KENNINGTON K.94.						
June germination count seedlings sq. yd.	926	1,146	1,008	1,090	820	810
Final stand (±87.5)	733	901	608	828	610	517
Mean height (±0.095), ins.	1.64	2.84	1.45	2.39	1.32	1.75
Usable plants (±62.8)	388	795	227	662	191	313
RINGWOOD R.91.						
June germination count seedlings sq. yd.	860	1,263	1,250	1,274	1,208	1,169
Final stand (±48.9)	881	1,294	1,302	1,269	1,141	1,170
Mean height (±0.109), ins.	0.91	2.94	2.47	3.25	0.97	1.63
Usable plants (±63.3)	65	1,201	1,055	1,197	127	589

At Ringwood, formalin, metham sodium and 'Mylone', applied as pre-sowing drenches, increased numbers more than PCNB broadcast dry and forked in, and more than Maneb applied as post-sowing drenches. Growth was very poor in untreated soil, and all treatments except PCNB substantially increased heights and dramatically increased numbers of usable plants. By contrast at Old Kennington none of the soil treatments significantly increased numbers; only formalin and Mylone increased growth and the number of usable plants. Similarly, seed treatment had little or no effect at Kennington, but at Ringwood it increased numbers in untreated soil, and in soils treated with the partial sterilants formalin, metham sodium and mylone, but not in soils treated with the fungicides PCNB and Maneb. The increases were larger from good quality seed (69% germination) than from poor quality (44% germination); the numbers sown of each quality having been adjusted to give a constant 1,800 viable seeds per square yard. See Table 12.

Table 12

INTERACTIONS BETWEEN SEED AND SOIL TREATMENTS

Final stand in number per sq. yard

Soil Treatment	Seed treatment and quality					
	Untreated		Thiram treated		Increase associated with Thiram	
	Poor	Good	Poor	Good	Poor	Good
*KENNINGTON K.*94.						
Untreated . .	671	781	724	756	+53	−25
Formalin . .	898	839	946	921	+48	+82
Metham sodium .	742	592	619	478	−123	−114
Mylone . .	670	822	900	920	+230	+98
PCNB . .	743	533	637	527	−106	−6
Maneb . .	527	552	585	403	+58	−149
*RINGWOOD R.*91.						
Untreated . .	794	831	842	1,055	+48	+224
Formalin . .	1,202	1,235	1,274	1,467	+72	+232
Metham Sodium	1,191	1,281	1,335	1,400	+144	+119
Mylone . .	1,271	1,224	1,193	1,389	−78	+165
PCNB . .	1,057	1,219	1,065	1,224	+8	+5
Maneb . .	1,096	1,182	1,163	1,238	+67	+56

Fungi were isolated from roots of seedlings sampled on several occasions from treated and untreated soils, in an attempt to explain the causes of some of these effects. Several species of *Pythium* were common isolates from Kennington and Ringwood early in the season, and some were also found at Wareham where damping-off is not a problem. Later *Cylindrocarpon radicicola* Wr. and *Phoma* spp. became the most frequent isolates, and species of *Fusarium*, although much less common, were more frequent at Kennington than at Ringwood. Much more information is required before the importance of these fungi, and the significance of changes in their numbers caused by soil treatments, can be assessed.

Experiments with Transplants

To learn more of the nature of the "formalin effect", seedlings raised in untreated and in formalin-treated seedbeds were transplanted at different ages into untreated and treated transplant beds. Formalin increased growth substantially at all stages, and seedlings raised in treated and untreated soil responded similarly to formalin treatment when transplanted. This was shown most clearly where seedlings had a whole season in seedbeds and a second season in transplant beds. See Table 13.

Table 13

MEAN EFFECTS AND INTERACTIONS OF FORMALIN APPLIED TO SEEDBED AND TRANSPLANT BED

TREATMENTS Seedbed	Transplant bed	Growth in seedbed inches	Growth in transplant bed inches	Final height of 1 + 1 tree (in.)
KENNINGTON K.97.				
—	—	2.63	5.86	8.49
Formalin	—	3.59	4.79	8.38
—	Formalin	3.04	7.53	10.57
Formalin	Formalin	3.70	7.22	10.92
Mean effect of formalin		+0.80	+2.05	
RINGWOOD R.94.				
—	—	1.44	5.91	7.35
Formalin	—	2.97	5.90	8.87
—	Formalin	1.57	8.39	9.96
Formalin	Formalin	2.92	8.81	11.73
Mean effect of formalin		+1.44	+2.70	

At Kennington the benefit gained from formalin in the seedbed was lost in the transplant bed, and transplant bed treatment was clearly the more effective. At Ringwood both seedbed and transplant bed treatment contributed to the final height of plants.

The results indicate that emergence losses and poor growth are two separate problems, although they often occur together in the same nursery. Partial soil sterilants like formalin often control both, whereas soil fungicides and seed dressings which are effective against emergence losses, have no effect on subsequent growth. Similarly in the transplant experiments the fact that seedlings raised in untreated and in treated soil both responded similarly to formalin when transplanted, suggests that poor growth in untreated soil was not due to root damage sustained early in the life of the seedling, such as non-lethal attacks by 'damping-off' fungi.

"Date of Sowing" Experiments

To test the persistence of formalin and the effectiveness of seed treatment under different environmental conditions, plots treated with formalin in December were sown on five different occasions between early March and the end of June. Sowings early and late in March produced the highest numbers and the best growth; no usable plants were obtained from seed sown at the end of May or June. Seed dressing increased numbers similarly for all sowings except those during May at Ringwood and during April at Kennington; these had little or no beneficial effect. Formalin increased growth of all sowings at both nurseries, a response being visible soon after emergence. It increased numbers more in early than in late sowings at Ringwood, but reduced numbers in all sowings except the earliest and the latest at Kennington.

NUTRITION EXPERIMENTS IN FOREST NURSERIES

Comparison of Sitka Spruce and Norway Spruce

By BLANCHE BENZIAN

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Between 1945 and 1958 Sitka spruce (*Picea sitchensis*) was grown in many experiments on nutritional problems in forest nurseries. In later experiments Norway spruce (*Picea abies*) was included because the transplants often showed a reddish-brown discoloration (a colour symptom different from any seen in Sitka transplants), and because in some production nurseries they developed a severe, often fatal, scorch, while the Sitka alongside remained healthy. In 1959 plots in two existing experiments on seedbeds (at Bagley (Oxford) and Wareham (Dorset) nurseries) and two on transplants (at Wareham) were split to compare the two species.

Seedlings

In the four years (1959–62) results for Sitka and Norway spruces were closely comparable, except that there were slight differences in colour symptoms, particularly those caused by K-deficiency. Both species showed large and consistent height responses to N and P at both Bagley and Wareham nurseries and also to K at Wareham; well-defined deficiency symptoms were caused by lack of N, K and Mg.

Transplants

From 1959 to 1961 both species responded similarly: there were moderate height increases from N, small or no increases from P and large increases from K. The reddish-brown discoloration previously observed in non-experimental beds was found to be a K-deficiency symptom (under these conditions Sitka spruce show purple colours).

Spring 1962 was very cold and windy, and June was dry; in July Norway spruce suddenly developed a severe rusty red "scorch" on many plots, and many plants subsequently died; on the same plots Sitka spruce remained normal and green. The P, K and Mg fertilizers had been dug in during the second half of February and the plants lined out in mid-April. This interval of seven to eight weeks between the two operations is normal. "Nitro-Chalk" and ammonium sulphate were applied as topdressings in Mid-May, end of June and end of July.

The damage was associated with dressings of KCl and of superphosphate, but $MgSO_4$ caused no harm. "Scorch" was particularly severe on plots long treated with ammonium sulphate which had become very acid; "Nitro-Chalk" greatly lessened the "scorch" in one experiment, but had little effect in the other. Again in 1962 characteristic K-deficiency symptoms developed in both species on the "no K" plots; where bracken-hopwaste composts had been given, no "scorch" occurred.

Damage resembling that in these experiments was reported from production nurseries over a wide area of England and Scotland in 1962. Severe fertilizer "scorch" of Norway spruce transplants described by Nemec (*Bodenk. u. PflErnahr.* (1939), 13, 35-72) was attributed to chloride injury on very acid soils. The trouble was aggravated by drought and by too short an interval between applying fertilizer and lining out; the number of dead trees increased rapidly as the interval decreased from 42 days to none.

Note—This paper has previously appeared in the *Annual Report of the Rothamsted Research Station*, 1962.

SITKA SPRUCE ON ARABLE LAND AT WOBURN

Twenty-five square-yard plots sown with Sitka spruce were added to a series of "reference plots" of farm crops and soft fruit started on old arable land in Stackyard Field at Woburn in 1960 (*Rep. Rothamst. Exp. Sta.* 1960, p. 55). Seedlings on unmanured plots were only 0.3 inch high at the end of the season, but those with full inorganic manuring (NPK+Mg) averaged 1.3 inches. Phosphorus and, to a less degree, nitrogen were responsible for this large increase—P increased the size nearly four times and N increased it by a third. This spectacular response to P on conifer seedlings is of special interest on a site where the other agricultural and horticultural crops responded only little to P. Neither K nor Mg had any effect on the size of seedlings, though slight yellowing typical of Mg-deficiency developed on the "no Mg" plots late in the season. Formalin (a "partial sterilant") added to plots with full inorganic manuring increased height by 60%; whatever its mode of action, formalin cannot, on this land, have controlled a population of soil pathogens specific to conifers, which have not grown on this site for at least 100 years.

Note—This paper has previously appeared in the *Annual Report of the Rothamsted Research Station*, 1961.

THE ACTION OF ENZYMES ON PLANT POLYPHENOLS: PART II

By SHEILA M. BOCKS and B. R. BROWN

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and

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The need for attempts to characterize leaf tannins by the use of enzymes was discussed in our 1962 report (Bocks, Brown & Handley, 1963) where the production of a phenolic intermediate as a result of the action of *Aspergillus niger* on (+)—catechin was described.

Experiments have now been carried out to investigate whether this organism is able to bring about any changes in the tannins which can be isolated from the leaves of various plant species.

Action of Aspergillus niger and Dilute Mineral Acid on the Tannin Isolated from the Leaves of Chamaenerion angustifolium

It has been suggested that the tannin extractable from the fresh leaves of a willow-herb, *Chamaenerion angustifolium* is a hydrolysable tannin, and it seemed probable that *Aspergillus niger*, which is a well-known source of the adaptive enzyme tannase, would be able to bring about the degradation of this tannin.

A mixture containing 0.15% KH_2PO_4, 0.06% NH_4NO_3, 0.05% $CaCl_2$ $6H_2O$, 0.05% Mg SO_4 $7H_2O$, 0.05% Na_2 B_4 O_7 and traces of Zn SO_4, Fe Cl_3, Cu SO_4 and Mn Cl_3 was sterilized and cooled before adding 0.5% *Chamaenerion* leaf tannin dissolved in the minimum quantity of 70% acetone/water. After standing to check the absence of contaminants the medium was inoculated with *Aspergillus niger* and incubated as a shaken culture at 25°C. 48 hours after inoculation 0.05 ml. portions of the culture fluid were chromatogrammed on paper. The presence of phenolic spots (Table 14) on the chromatograms was demonstrated by spraying with Fe $Cl_3/K_3Fe(CN)_6$. The phenolic spots were not detected in chromatograms of samples of fluid from flasks in which the tannin was incubated in the absence of the organism or from flasks in which the organism was present but from which the tannin was absent. See Table 14.

Table 14

CHARACTERISTICS OF THE PHENOLIC SPOTS ARISING FROM CHAMAENERION LEAF TANNIN

Chamaenerion leaf tannin treated with:		Rf. (²) values in B.A.W. (¹)	Rf. values in 2% Acetic acid
Aspergillus niger	(1)	0.47	0.098
	(2)	0.59	0.32 stronger spot ? gallic acid
0.1 N H Cl	(1)	0.275	0.606
	(2)	0.245	0.695
	(3)	0.59	0.34 strongest spot
	(4)	0.796	0.248 ? gallic acid
0.2 N H_2SO_4	(1)	0.19	0.61
	(2)	0.59	0.33 stronger spot ? gallic acid
Characteristics of an authentic sample of gallic acid		0.59	0.33

Note—(1) B.A.W. = *n*-Butanol-Acetic acid-Water (4 : 1 : 5 v/v)
(2) Rf =Stands for a chromatographic ratio.

Two phenolic spots were obtained as a result of the action of *Aspergillus niger* on *Chamaenerion* leaf tannin; one of the spots had the same characteristics as an authentic specimen of gallic acid.

At the same time the effect of dilute mineral acid on the *Chamaenerion* leaf tannin was examined.

(a) *Action of* 0.2 *N* H_2SO_4

On treatment of the *Chamaenerion* leaf tannin with 0.2 N H_2SO_4 for 30 minutes at 80°C two phenolic spots were detected when the hydrolysate was chromatogrammed. The spot giving the more intense reaction had similar characteristics (Rf values) to those of authentic gallic acid.

(b) *Action of* 0.1 *N HCl*

When similarly treated with 0.1 N HCl the *Chamaenerion* leaf tannin yielded several phenolic spots on chromatograms and again the spot giving the most intense reaction had the characteristics of gallic acid.

These findings suggest that *Chamaenerion* leaf tannin may well be a hydrolysable tannin.

Action of Aspergillus niger and Dilute Mineral Acids on Calluna Leaf Tannin

It has been found previously (1) that although phenolic intermediates could not be detected when *Aspergillus niger* was grown on a mineral salt medium containing (+)—catechin as the sole source of carbon, a phenolic intermediate could be obtained if the organism were first grown on aqueous malt extract solution which was subsequently replaced by a mineral salt solution containing 0.5% (+)—catechin.

Aspergillus niger was therefore grown, as a shaken culture to avoid spore formation, on 3% aqueous malt extract solution for three days at 25°C and the resulting mycelium was then washed with sterile distilled water. 0.1% *Calluna vulgaris* (common heather) leaf tannin, dissolved in the minimum quantity of 70% acetone/water, was added to a sterilized solution containing 0.3% $(NH_4)_2HPO_4$, 0.1% KH_2PO_4, 0.8% $(NH_4)_2SO_4$ and traces of Zn SO_4, Fe Cl_3 Cu SO_4 and Mn Cl_2. The mixture was allowed to stand to check the absence of contaminants before adding the washed mycelium and shaking for 72 hours at 25°C. The fluid was separated from the mycelium by filtration through glass wool and then extracted with ethyl acetate. The ethyl acetate extract was concentrated in a rotary evaporator and the concentrate chromatogrammed on paper.

In this experiment smaller phenolic molecules derived from the *Calluna* leaf tannin were also detected in the controls (aqueous *Calluna* leaf tannin-nutrient salt mixtures incubated in the absence of *Aspergillus niger* mycelium) as well as in the presence of *Aspergillus niger* mycelium. This did not occur in the previously reported (1) experiment with (+)—catechin and it is suggested that the reaction of the medium (pH 7.0) or one or more of its salt constituents may have decreased the stability of the tannin and resulted in slight degradative fission. It is hoped to investigate this further. A phenolic compound having different Rf values to those of the phenolic materials produced in the control flasks was detected in extracts of the fluid from the flasks to which *Aspergillus niger* mycelium had been added. This compound is under chemical investigation.

In previous work on the effect of mineral acids on condensed tannins, concentrated acids have been used and although some recognizable degradation products, e.g. cyanidin and delphinidin, have been obtained the bulk of the tannin became a brown, insoluble and intractable material.

On treatment of *Calluna* tannin with a range of concentrations of hydrochloric acid it was found that at concentrations below 0.1N the production of brown insoluble products from *Calluna* tannin did not occur even on heating for 2 hours at 80°C. Increases in the amount of cyanidin produced as the treatment continued were followed on the spectrophotometer (λ max. 535 $m\mu$).

Two phenolic spots were detected ($FeCl_3/K_3Fe(CN)_6$) on paper chromatograms of *Calluna* leaf tannin treated with 0.1 N HCl (Table III).

(+)—catechin has also been treated with dilute mineral acid. On heating with 0.1 N HCl for 30 mins. at 80°C followed by paper chromatography, four phenolic substances having the characteristics shown in Table 15 were detected:—

Table 15

CHARACTERISTICS OF PHENOLIC SUBSTANCES

Spot No.	1	2	3	4
Rf. (1) in 2% acetic acid	0.615	0.81	0.05	0.96
Rf. in B.A.W. (2) 4 : 1 : 5	0.73	0.93	0.65	0.38

Note—(1) Rf. stands for a chromatographic ratio.
(2) B.A.W. = *n*-Butanol-Acetic acid-Water (4 : 5 : 1 v/v)

When (+)—catechin was treated with 2 N HCl the phenolic material of spot (1), obtained when (+)—catechin was treated with 0.1 N HCl, was not detected.

Action of 0.1 N HCl on the Leaf Tannins of Other Species

Treatment of the leaf tannins of various species with 0.1 N HCl also resulted in degradation with the production of smaller phenolic molecules which could be detected on paper chromatograms. Their characteristics are given in Table 16.

Fraxinus excelsior (ash) leaf tannin appeared to differ from the tannins from the other species in that it gave rise to 3 phenolic compounds which could be detected by their silver-white fluorescence in ultra-violet light.

Ability to Grow on, and Changes Produced in, Calluna Leaf Tannin for Various Species of Fungi

In the 1962 *Report on Forest Research*, page 93 the ability of various species of fungi to grow on, and to produce changes in, (+)—catechin were described. A similar investigation has now been carried out using *Calluna* leaf tannin.

Various species of fungi were inoculated on to the following medium in petri dishes: 0.15% KH_2PO_4, 0.06% NH_4NO_3, 0.05% $CaCl_2$ $6H_2O$, 0.05% $MgSO_4$ $7H_2O$, 0.05% $Na_2B_4O_7$, 1.5% Agar, a trace of $ZnSO_4$, $FeCl_3$, $CuSO_4$ and $MnCl_2$. 0.1% *Calluna* leaf tannin (containing residual NaCl), dissolved in the minimum quantity of 70% acetone/water, was added to the above mineral salt-agar mixture after it had been sterilized by autoclaving followed by cooling to 45°C. Before inoculation the medium was incubated to check the absence of contaminants. After inoculation the cultures were incubated at 25°C and the results shown in Table 17 were obtained.

Table 16

CHROMATOGRAPHIC CHARACTERISTICS OF THE POLYPHENOLIC ($FeCl_3/K_3Fe(CN)_6$) MATERIALS RESULTING FROM THE ACTION OF 0.1 N HCL ON LEAF TANNINS ISOLATED FROM VARIOUS PLANT SPECIES

Species	Spot No.	Rf. in *n*—Butanol—Acetic Acid-Water (4 : 1 : 5 v/v)	Rf. in 2% Acetic Acid
Taxus baccata, Yew . .	1	0.264	0.94
	2	0.82	0.395
Picea abies, Norway spruce .	1	0.47	0.96
Fagus sylvatica, beech . .	1	0.28	0.97
Betula spp., birches . . .	1	0.415	0.98
	2	0.63	0.39
Pteridium aquilinum, bracken .	1	0.43	0.97
Larix decidua, European larch .	1	0.34	0.98
	2	0.68	0.33
Calluna vulgaris, common heather	1	0.61	0.79
	2	0.62	0.47
	3	0.87	0.57
	4	0.655	0.48
	5	0.74	0.39
	6	0.39	0.93
Pseudotsuga taxifolia, Douglas fir	1	0.4	0.95
	2	0.75	0.37
	3	0.56	0.27
	4	0.36	0.318
	5	0.65	0.46
Acer spp., maples . . .	1	0.56	0.32
	2	0.6	0.18
	3	0.29	0.97
Quercus spp., oaks . . .	1	0.64	0.34
	2	0.40	0.04
	3	0.59	0.92
	4	0.327	0.98
Castanea sativa, sweet chestnut .	1	0.66	0.38
	2	0.61	0.47
	3	0.47	0.55
	4	0.72	0.50
	5	0.34	0.985
	6	0.61	0.29
Acer pseudoplatanus, sycamore .	1	0.63	0.33
	2	0.55	0.28
	3	0.17	0.78
Fraxinus excelsior, ash . .	1	0.86	0.28
	2	0.28	0.45
	3	0.32	0.955
	4	0.88	0.77
Bamboo (very weak spots) .	1	0.71	0.95
	2	0.37	0.97
	3	0.19	0.16
	4	0.39	0.56
	5	0.48	0.42

Rf. stands for a chromatographic ratio.

Table 17

RESULTS AFTER INCUBATION

Organism	Production of orange coloured zone in the medium around the colony		Growth
	After incubation for 24 hours	After incubation for 1 week	
Polyporus versicolor	++	+++	good
P. sanguineus	+	++	poor
P. hirsutus	+	++	poor
P. abietinus	+	++	poor
Stereum hirsutum	+	+++	good
Marasmius scorodonius	+	++	poor
Trametes gibbosa	+	++	poor
Collybia butyracea	+	++	poor
Hypholoma fasciculare	+	++	poor
Daldinia concentrica	—	+	poor
Cladosporium spp.	—	+	poor
Polyporus betulina	—	+	poor
Neurospora crassa	—	+	poor
Penicillium solitum	—	—	poor
Aspergillus niger	—	—	poor
Aspergillus flavus	—	—	poor
Penicillium estinogenum	—	—	poor
Alternaria spp.	—	—	poor

The production of the orange coloured zone by various fungi is presumably due to the p-diphenolase (laccase) activity of these fungi, since a similarly coloured product was obtained when *Calluna* leaf tannin was exposed to the action of an extracellular enzyme preparation from *P. versicolor* obtained as described in *Report on Forest Research for* 1962, page 93.

It is interesting that *D. concentrica*, *P. betulina*, *N. crassa*, and *Cladosporium* spp. also produced an orange coloured zone in the *Calluna* leaf tannin—containing agar medium after incubation for one week. In these organisms the enzyme is probably adaptive since no trace of phenolase activity could be detected in culture fluids from cultures of these organisms grown on 3% malt for 3 weeks, the fluids being assayed for activity by the use of 2, 6-dimethoxyphenol (Brown and Bocks, 1963).

It is inferred, from previous work with phenolase, that the orange substance produced from *Calluna* leaf tannin may be quinonoid in nature.

Chromatographic investigation of the orange product, obtained by incubation of *Calluna* leaf tannin in the presence of the extracellular enzyme from *P. versicolor* at various pH values (4.0–8.0), showed that it did not run in 2% acetic acid and gave no reaction with $FeCl_3/K_3Fe(CN)_6$.

Since most of the fungi grew poorly when *Calluna* leaf tannin was the sole carbon source, the effect of addition of 1% malt to this medium was examined. It was found that all the species of fungi now grew well so that in the presence of malt extract the concentration of *Calluna* leaf tannin used is not inhibitory to growth.

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BIOLOGY OF FOREST SOILS

By G. W. HEATH

Rothamsted Experimental Station, Harpenden, Herts.

The rate of disappearance of oak and beech leaf disks, laid on the surface of undisturbed woodland soil, has been compared with their rate of disappearance on similar soil from which earthworms have been removed by hand and thereafter kept out with terylene netting. Disks were laid on this soil in November at the two sites described in previous reports. Samples were taken, from equal areas, every 2 weeks for 12 months. The percentage disappearance of the leaf lamina, of these samples, was estimated (Figs. 3 and 4).

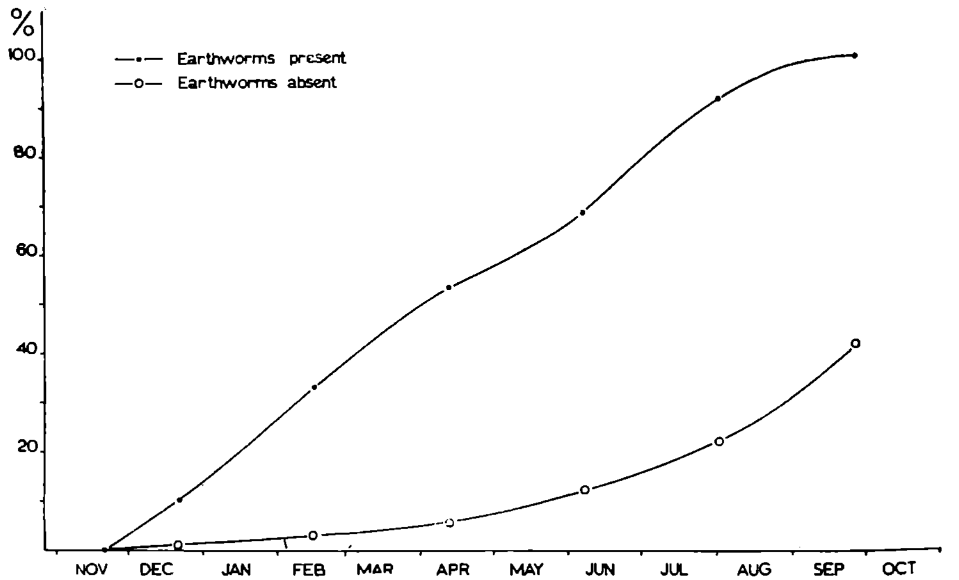

FIGURE 3. Percentage disappearance of oak leaf disks.

Without earthworms only about 25% lamina of the beech disk lamina still found on the soil had disappeared by the end of the experiment. (But some whole disks were lost from the edges of these plots by worms from adjacent soil and the values shown have been corrected to account for this.) By contrast, about 50% of the oak leaf lamina had disappeared on similarly treated plots.

Where earthworms are present both beech and oak had completely disappeared by the next autumn.

PLATE 1. Hinson, Kitching & Fourt: Soils.
Recording flow gauge in drainage experiment, Halwill Forest, Devon.

PLATE 2. Buszewicz: Forest Tree Seed.
Refrigerated Chamber in the Central Seed Store, Alice Holt.

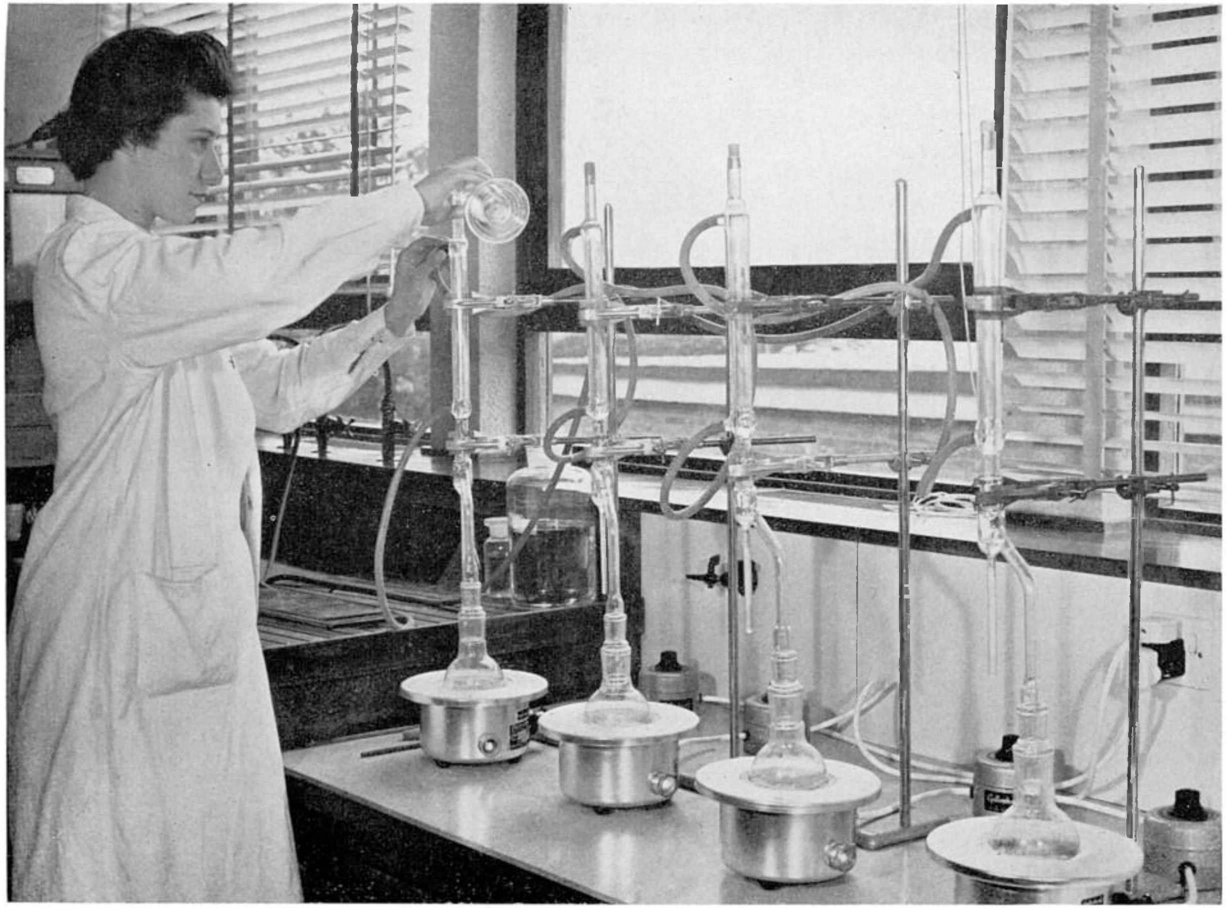

PLATE 3. Buszewicz: Forest Tree Seed.
Toluene distillation apparatus for estimation of seed moisture.

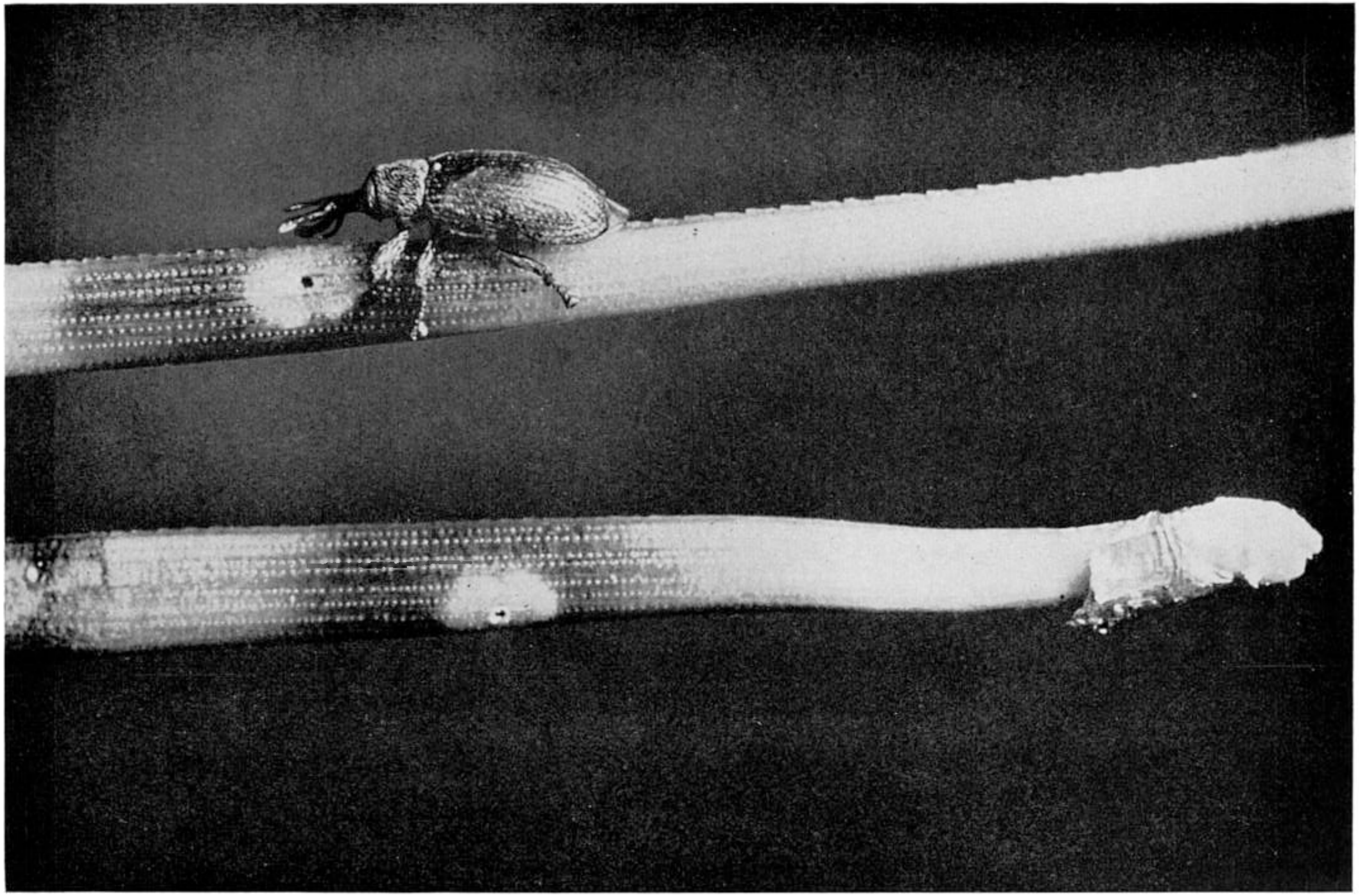

PLATE 4. Bevan: Entomology.
The small weevil *Braconyx pineti* feeding on the needles of Lodgepole pine, *Pinus contorta*.

PLATE 5. Lines and Aldhous: Silvicultural Investigations: Provenance.
Lodgepole pine from Hollis, Alaska, growing well in an exposed shelter plantation at Watten, Caithness.

PLATE 6. Matthews, Faulkner, and Mitchell: Genetics. Conversion of Seed Sources to Seed Stands: A Corsican pine normal seed stand after its first special thinning; Thetford Chase, Norfolk.

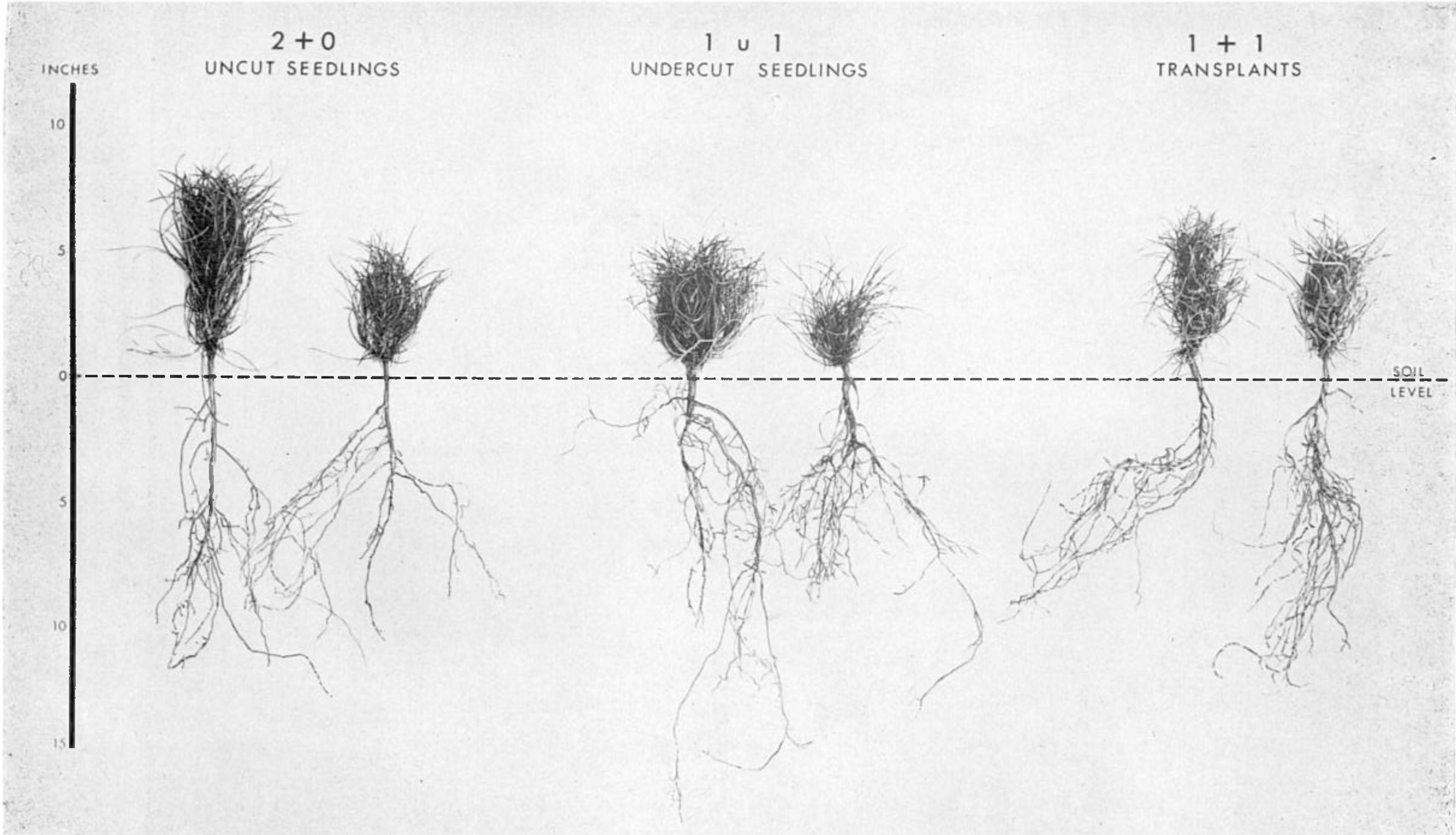

PLATE 7. Atterson: Survival and Growth of Undercut Seedlings
Two-year-old plants of Corsican pine showing growth under three regimes: *Left*, undisturbed **2 + 0 seedlings**; *centre*, undercut **1 u 1 seedlings**: *right*, **transplanted** 1 + 1 transplants.

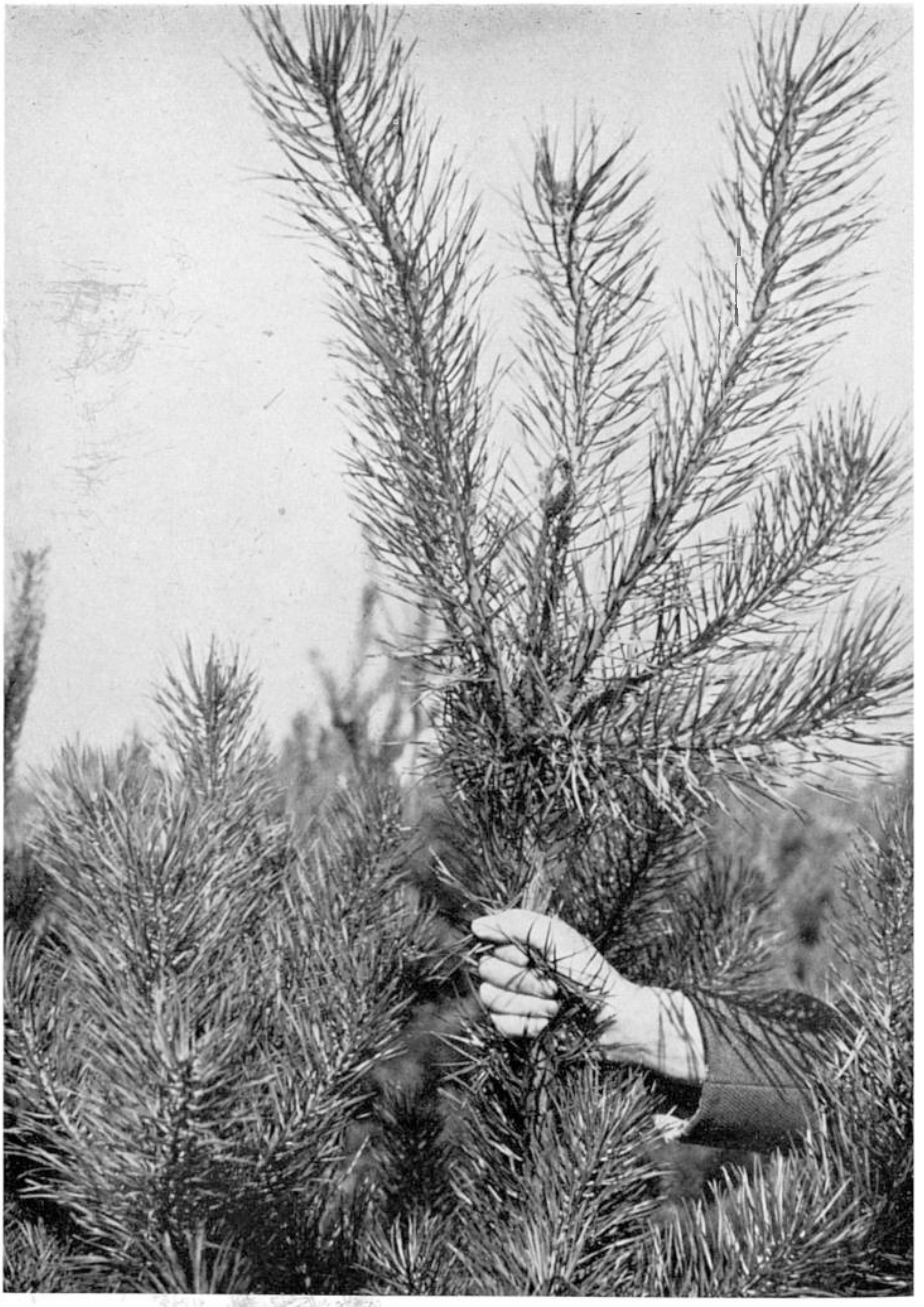

PLATE 8. Lines: Scots Pine Provenance.
An eight-year-old tree of the Glen Tanar Provenance, growing at Laiken Forest, Nairn. The leading shoot has been killed by the Pine shoot moth, *Evetria turionana*, and vigorous growth has followed from side buds.

PLATE 9. Zehetmayr, Work Study.
A type of horse sledge, a Norwegian "Skidding arch", under trial for hauling pulpwood down a rack.

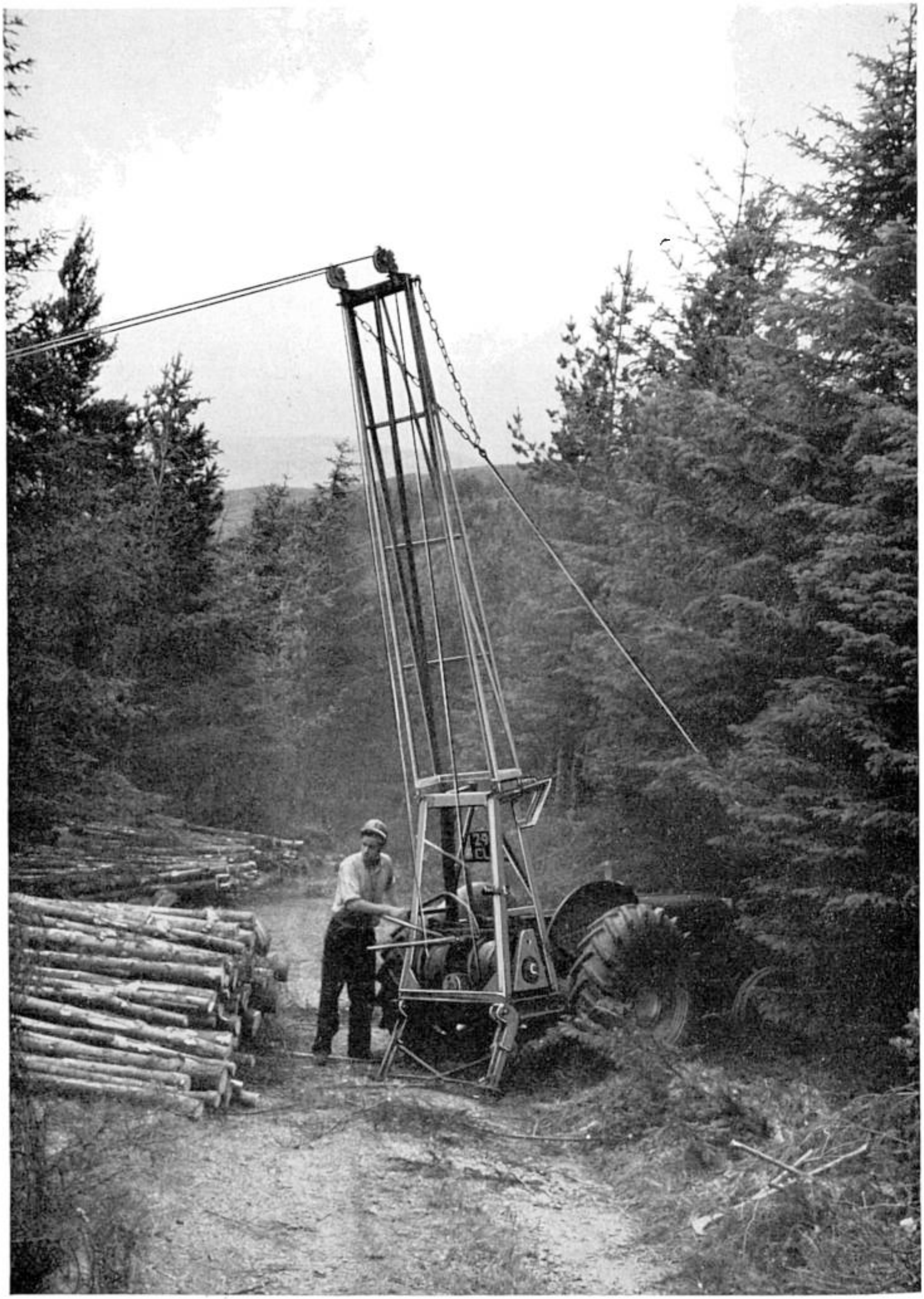

PLATE 10. Zehetmayr, Work Study, and Shaw, Machinery Research: General view of Norwegian Isachsen Double Drum winch. Note drums at rear of tractor, and two hauling lines at head of tower.

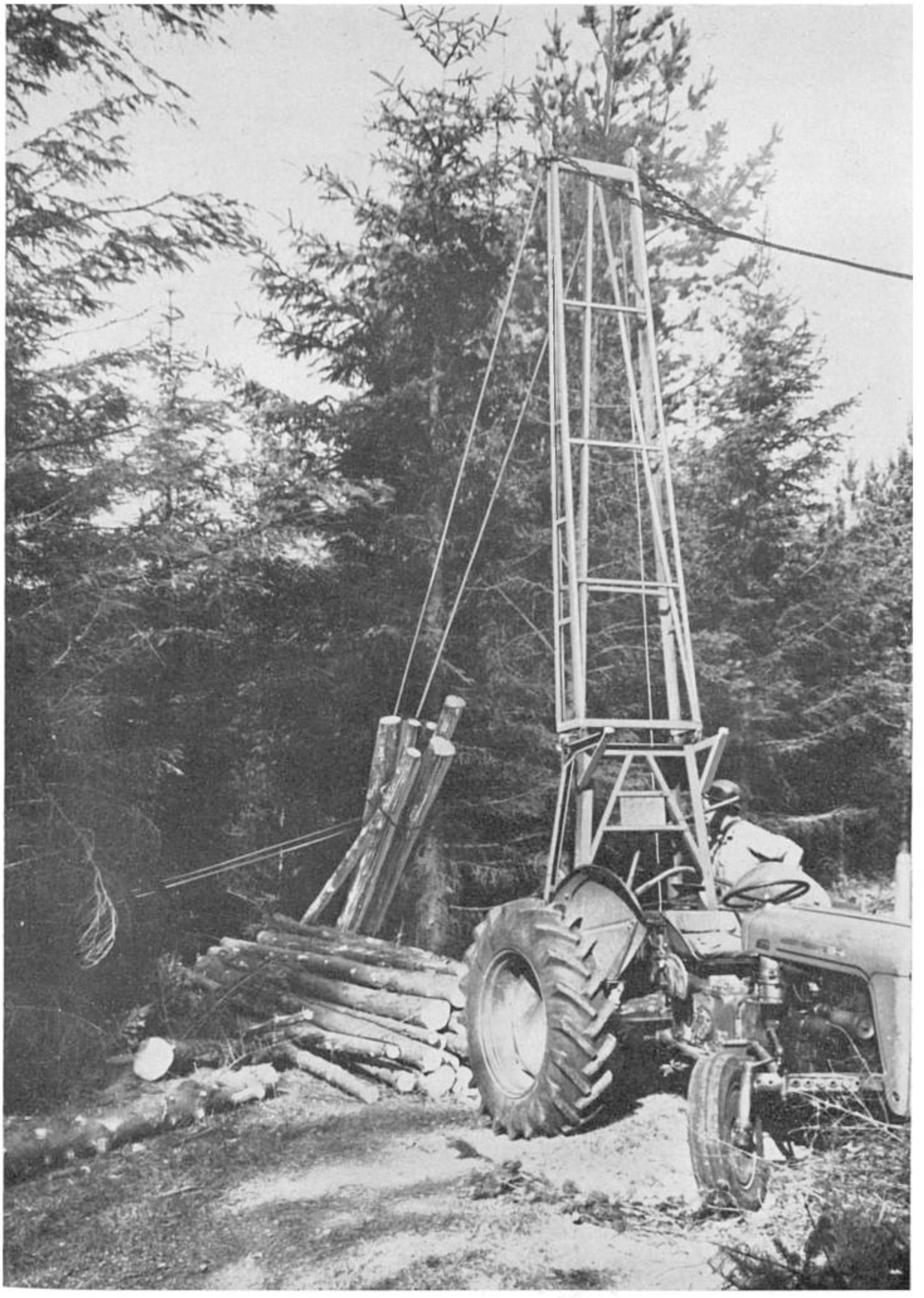

PLATE 11. Zehetmayr, Work Study, and Shaw, Machinery Research: Isachsen Double Drum winch in use, hauling logs to roadside.

PLATE 12. Zehetmayr, Work Study, and Shaw, Machinery Research:
A lorry-mounted crane, the Swedish H.I.A.B. Elefant with hydraulic grab, loading a twelve-ton trailer with pulpwood.

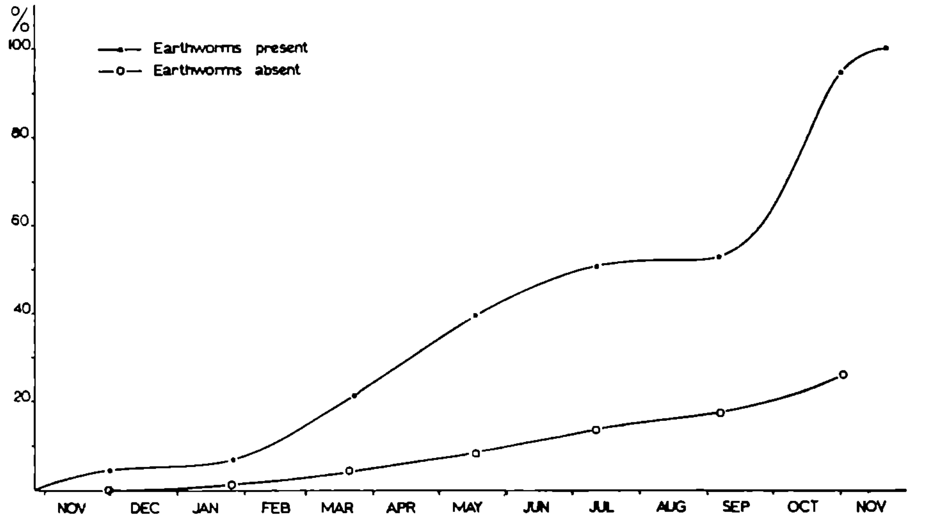

FIGURE 4. Percentage disappearance of beech leaf disks.

The rates of disappearance of oak and beech disks when earthworms are excluded differed little for most of the year, but oak disappeared a little faster than beech in the autumn. When earthworms are not excluded, oak disappeared faster than beech in spring and summer, but in autumn beech disappeared more quickly than oak.

The summer and autumn of 1962 were wet and little decrease in the rate of leaf disappearance, as observed in other seasons, is shown in the graphs. There is a slight indication of a decreasing rate in Fig. 3 and this coincides with a dry period in late spring, but the decrease in rate of disappearance of beech during July and August cannot be so explained and may be caused by the longer time taken for beech to become acceptable to soil animals once it has been dried out.

In the experiment with oak disks, the top three inches of woodland soil was heat sterilised as an additional treatment. The sterilised soil was replaced in the woodland, but separated from the soil around and beneath it by terylene mesh thought to be fine enough to exclude all animals. Oak leaf disks were placed on top of this soil and covered with the fine terylene. The disks remained intact for 3 months, but after this time the plots became infested with Tipulid larvae, and leaves disappeared fastest in mid summer, quite unlike the disappearance rates seen in other experiments.

Experiments in collaboration with Dr. Edwards, mentioned last year, has shown that green oak leaf disks, put in the soil in the largest mesh bags in June, completely disappeared after 16 months, whilst nearly 18% of similarly treated beech disks still remained. During the experiment oak disks were consistently fragmented more quickly than beech. Leaf disks of both oak and beech, from which earthworms were excluded, only disappeared at about a third the rate achieved when earthworms were allowed to feed. Leaf disks disappeared more rapidly in pasture soil than on the surface of the woodland soil, probably because of a more diverse fauna, because the old pasture soil is kept fallow and offers little food supply to the fauna, and because disks buried in the soil are always damp.

It was reported last year that the thicker, tanned, "sun" leaves, picked in September, were not as readily eaten as the thinner shade leaves. After about 9 months the tanned leaves became even more acceptable than the residue of the green leaves which had been put out in June. The rate and amount of disappearance from the September-picked leaves therefore became greater than the rate and amount from the June-picked leaves. It is not yet known how these tanned leaves become acceptable to animals, but two new experiments have been started to investigate various possibilities.

In one experiment oak and beech leaves were collected weekly from June to November, and stored at 0°C in sealed bags; disks cut from them have been placed in the soil at the same time (late November) to see if age of leaf has any effect on palatability. In another experiment leaves of oak, beech, ash, lime, elm, birch, blackberry, maize, kale, beet, bean and lettuce were buried in woodland and pasture soil in mesh bags and their rate of disappearance is being measured. The softer tissues of Kale, beet, bean and lettuce had completely disappeared after 2 months.

Dr. Tilley of the Grassland Research Institute has kindly determined the *in vitro* digestibility of some samples of oak and beech leaf litter, using rumen organisms. Oak appeared to be about twice as digestible as beech to these organisms, and in oak about 40% of the total digestibility was made up of water soluble or acid-pepsin extractable material, and the remainder was of fibrous material needing specific digestive processes (involving the enzyme cellulase). There is no evidence that the flora of the rumen resemble the flora in the gut of soil invertebrates, but the difference found in digestibility of the oak and beech leaves is interesting in view of their different rates of disappearance.

STUDIES ON THE MYCOLOGY OF SCOTS PINE LITTER

By A. J. HAYES

Department of Forestry, University of Edinburgh

With the assistance of a Forestry Commission grant, research on this subject was begun in October 1962, the aims being as follows:

(1) To determine the fungus flora on leaf and twig litter of Scots pine (*Pinus sylvestris* L.) as it decays.

(2) To define, if possible, the distribution of fungi in the experimental area.

(3) To elucidate the physiology of these fungi, using a number of pure substrates.

(4) To ascertain the exact role of these fungi in the decomposition of Scots pine litter, and hence determine the precise fate of each substance occurring in the leaf.

The first part of this programme has been implemented, using a small defined area of the Black Wood of Rannoch, (Rannoch Forest, Perthshire). Weekly collections of leaf litter from the L, F, and H layers, and also of twig litter, have been made, and have been plated out direct on to 2% malt agar. A parallel series, previously surface sterilised with 0.1% silver nitrate solution, has also been plated out. Most of the work to date has been concerned with the identification of fungi developing on these plates.

The bulk of newly fallen litter seems to be colonised by a species of *Phoma*. Occurring commonly on older litter and twigs were species of *Absidia*, *Mortierella*, *Mucor*, *Aspergillus*, *Botrytis*, *Cephalosporium*, *Cladosporium*, *Penicillium* and *Trichoderma*. In addition material surface-sterilised prior to plating-out has yielded species of *Fomes*, *Rosellinia* and *Stemphylium*, together with a number of sterile mycelia, including some Basidiomycete mycelia.

There are some indications that the fungus flora varies markedly in different parts of the Black Wood, as random collections made in other areas at various times have shown a replacement of certain of the species present in the experimental area by other species.

CHEMICAL CHANGES IN FOREST LITTER SECOND REPORT, MAY 1963

By J. TINSLEY and AILEEN LENNOX

Department of Soil Science, University of Aberdeen

The aims of the present study were set out in the first report by Tinsley and Hance (1962). This included details of the amounts of urea, ammonium sulphate, ammonium phosphate and ground chalk applied to two blocks of field manurial plots and to microlysimeters established under Scots Pine at Bramshill, Hampshire, in the Spring of 1962. Subsequently Dr. Hance resigned and has been succeeded in the Research Fellowship by Miss A. M. Lennox.

Analysis of Samples from Experimental Plots

Originally samples of the L, F, and H horizons of the surface organic matter were taken for analysis to determine the composition before the fertilizer treatments were applied, and also to provide material for setting up experimental columns in the laboratory. Since then two sets of samples have been collected from each of the experimental plots, the first batch on 22nd October 1962 to detect changes in composition during the summer immediately after application, and the second batch on 25th April 1963 to follow any changes during the succeeding winter. Further samples will be taken in the Autumn of 1963.

The samples were dried to determine the moisture contents. Then the coarse residues of undecomposed needles, cones and twigs were separated from the more humified organic matter by screening on a sieve with holes 2 mm. in diameter. The fractions retained and passed by the sieve were weighed separately, and the organic matter and nitrogen contents of the latter were determined.

The results from the first sampling are summarized in Table 18. They show that the mean moisture content at the time was 48.5 per cent, with slightly more on the unlimed plots and slightly less on the limed, though the differences were not significant. Of the dried material, on average 68.9 per cent passed the sieve and there was no difference between the unlimed and limed plots. Of this more humified material the mean organic matter content was 66.6 per cent, the value for the unlimed plots being 70.1 and for the limed plots 63.2, clearly the applied lime has increased the ash content of the humified organic matter, as would be expected.

The mean nitrogen content expressed as a percentage of the ash-free organic matter was 1.47, the value for the unlimed plots being 1.45 and for the limed plots 1.50. The liming treatment, therefore, appears to have brought about a slight increase in total nitrogen content of the humified organic matter, probably mainly as a result of increasing the rate of microbiological humification. Certainly the limed plots showed a somewhat darker brown appearance at the time of sampling.

The effects of liming with ground chalk at 30 cwt. per acre are demonstrated by the pH values which are surprisingly consistent. The different rates of nitrogen fertilizers had less effect on the pH values than the form of nitrogen. Whereas the mean value for the ammonium sulphate treatments was the lowest at 3.37, the mean of the ammonium phosphate treatments was 3.47, that for the urea 3.77. The corresponding means for the limed plots were: 6.05, 5.85 and 5.94.

Analysis of Drainage Samples from Microlysimeters

The two Blocks were first established on 26.3.62, but unfortunately the Block I set was damaged by marauding animals so these had to be restarted on 5.6.1962, and both sets were thenceforth protected by a covering of wire netting. However the two Blocks cannot now be considered as precise duplicates though the composition of the drainage water shows similar trends in each. See Table 18.

Table 18

COMPOSITION OF SAMPLES FROM BLOCKS I & II ON 22.10.62

Moisture Content of Samples
Mean Percentages, each from 2 limed and 2 unlimed plots.

Fertilizer	Urea	Ammonium Sulphate		Ammonium Phosphate
Level				
50 lbs N/acre	50.3	51.0		47.5
100 lbs.	45.6	47.2		43.3
200 lbs.	52.3	48.8		50.4
Treatment Means	49.4	49.0		47.1
Overall Mean	48.5±1.2		Unlimed	50.3±2.3
			Limed	46.7±5.1

(b) *Proportion of Dry Sample Passing 2 mm. sieve*
Mean Percentages.

Fertilizer	Urea	Ammonium Sulphate		Ammonium Phosphate
Level				
50 lbs N/acre	69.6	71.2		67.5
100 lbs.	65.8	72.2		59.3*
200 lbs.	74.9	67.5		72.3
Treatment Means	70.1	70.3		66.3
Overall Mean	68.9±0.5		Unlimed	68.6±1.9
			Limed	69.1±3.0

* Including one abnormally low result

Table 18—*continued*

(c) *Organic Matter Content of Material Passing 2 mm. sieve*
Mean Percentages.

Fertilizer	Urea	Ammonium Sulphate		Ammonium Phosphate
Level				
50 lbs N/acre	68.6	70.4		65.6
100 lbs.	62.3	66.6		68.6
200 lbs.	66.9	65.9		65.1
Treatment Means	65.9	67.6		66.4
Overall Mean	66.6±0.5		Unlimed	70.1±1.8
			Limed	63.2±2.3

(d) *Nitrogen Content of Organic Matter Passing 2 mm. sieve*
Mean Percentages.

Fertilizer	Urea	Ammonium Sulphate		Ammonium Phosphate
Level				
50 lbs N/acre	1.49	1.40		1.53
100 lbs.	1.38	1.41		1.34
200 lbs.	1.56	1.60		1.55
Means	1.48	1.47		1.47
Overall Mean	1.47±0.001		Unlimed	1.45±0.004
			Limed	1.50±0.005

(e) *pH Values of Samples Passing 2 mm. Sieve*

Fertilizer	Urea		Ammonium Sulphate		Ammonium Phosphate	
Level	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed
50 lbs N/acre	3.59	5.89	3.35	5.98	3.30	6.00
100 lbs.	3.65	5.81	3.20	6.01	3.34	5.89
200 lbs.	4.06	6.12	3.52	6.15	3.78	5.66
Means	3.77	5.94	3.37	6.05	3.47	5.85

Six lots of drainage water from Block II, and five from Block I, have so far been collected, measured and analysed for total and ammonia nitrogen and for total carbon. Results for Block II are presented graphically in Figs. 5–7 and 8–10. Figs. 5–7 show that the total amount of nitrogen leached from the organic horizons depends firstly on the level of fertilizer nitrogen applied, but there are appreciable differences in the effect of the different forms of nitrogen. Thus, from Fig. 5, urea at the highest rate (N_3) appears to promote rapid movement of nitrogen downward, but a comparatively small proportion of that collected in the leachate was in the free ammonium form, and reference to Fig. 8 reveals that large quantities of organic carbon also passed into the leachate, indicating that the urea promoted early solution of humus compounds, as was noted in the previous report. Liming increased the amount of ammonia and organic matter in the leachates from the N_3 urea treatments. The N_2 and N_1 levels of urea had smaller effects, and the interaction of lime was relatively less.

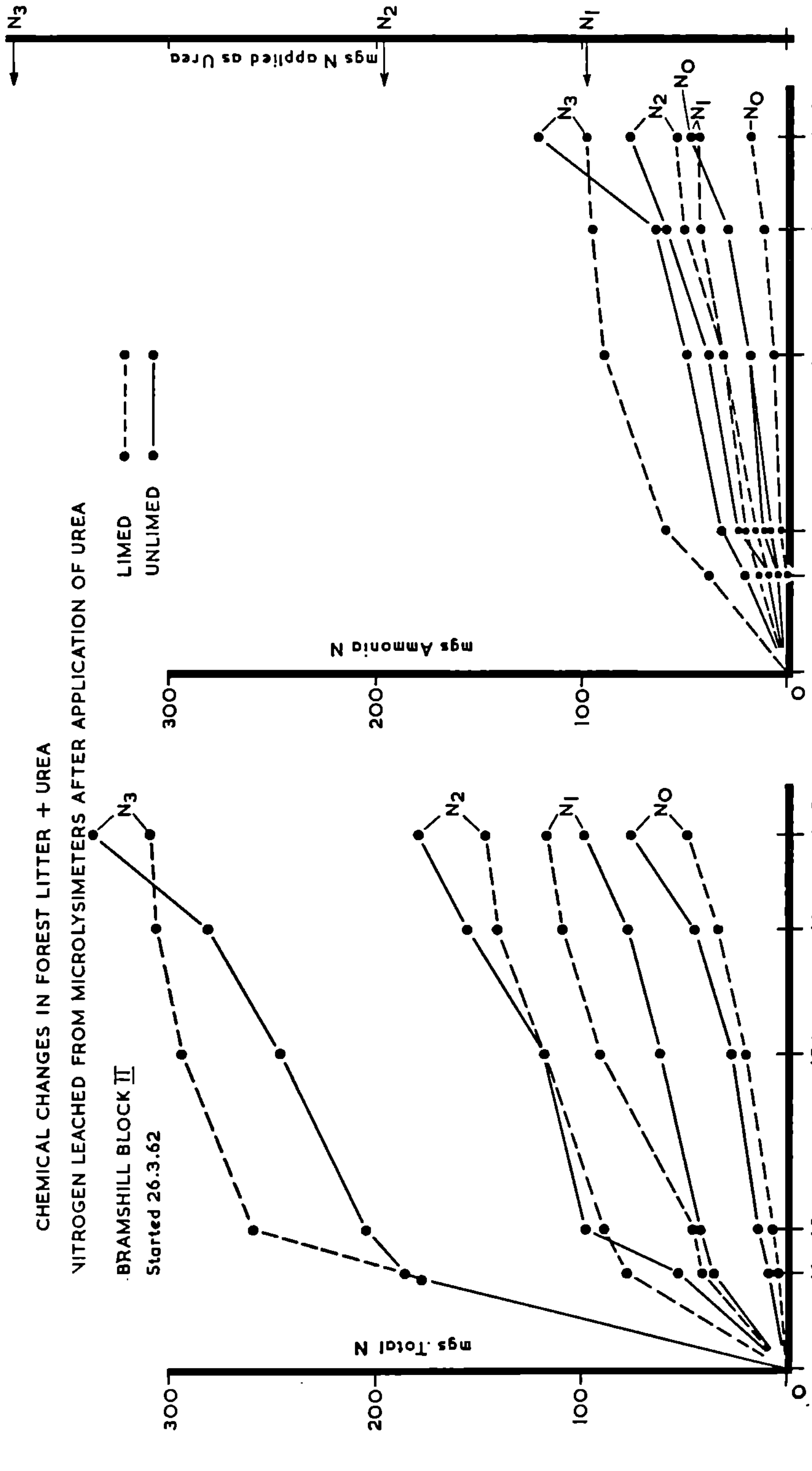

FIGURE 5. Nitrogen leached from Microlysimeters: Urea.

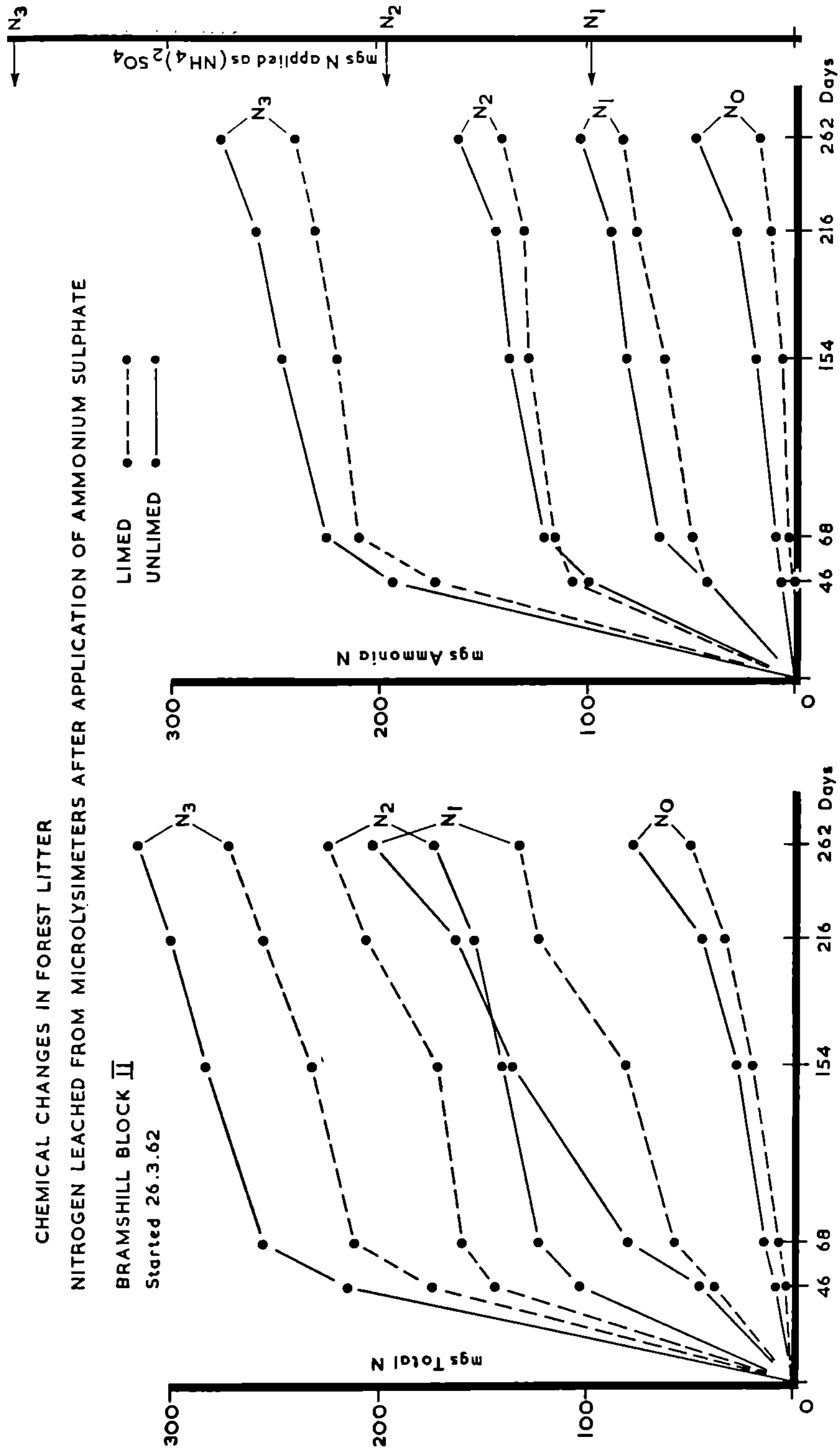

Figure 6. Nitrogen leached from Microlysimeters: Ammonium sulphate.

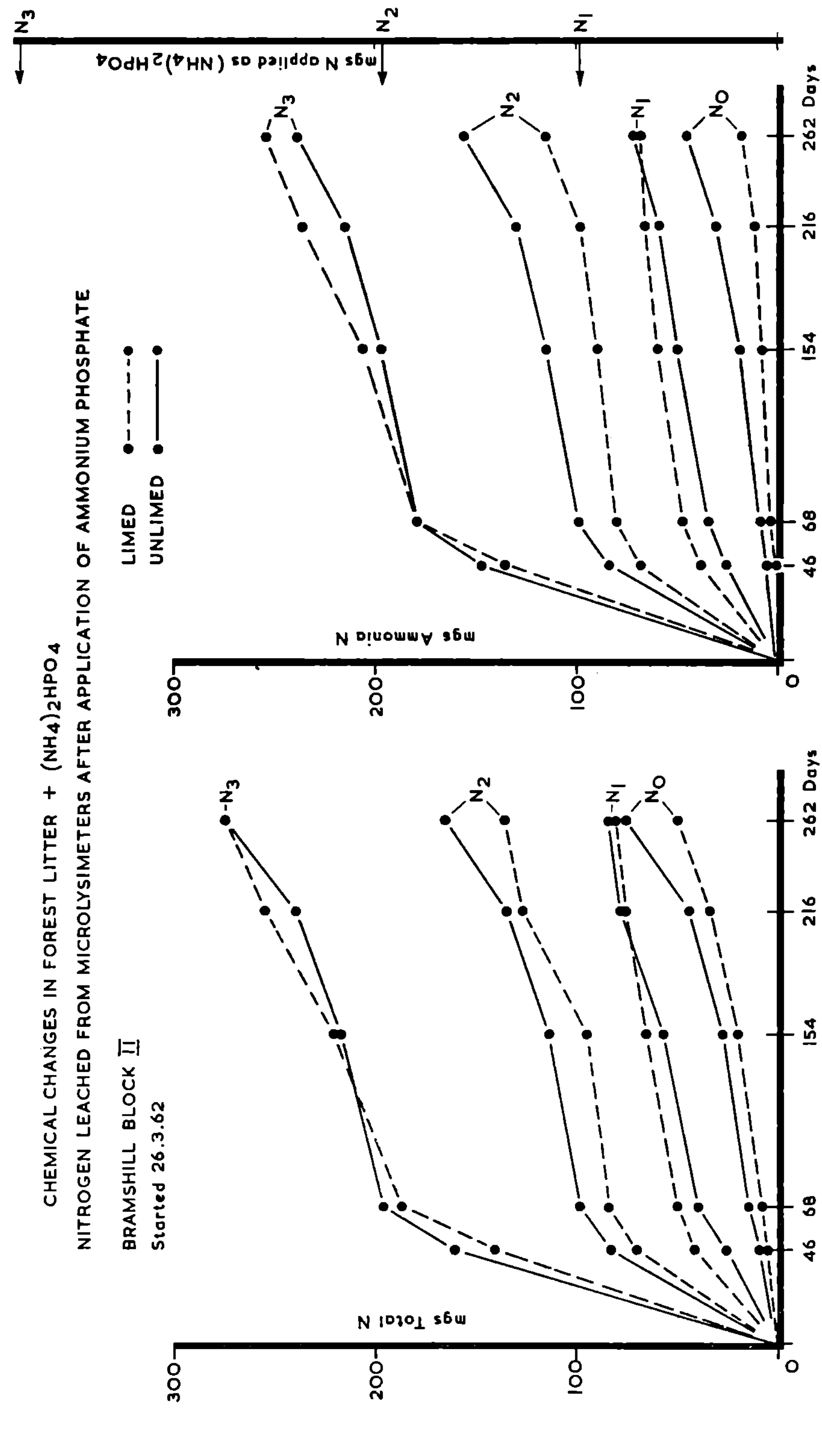

FIGURE 7. Nitrogen leached from Microlysimeters: Ammonium phosphate

CHEMICAL CHANGES IN FOREST LITTER + UREA

CARBON LEACHED FROM MICROLYSIMETERS AFTER APPLICATION OF UREA

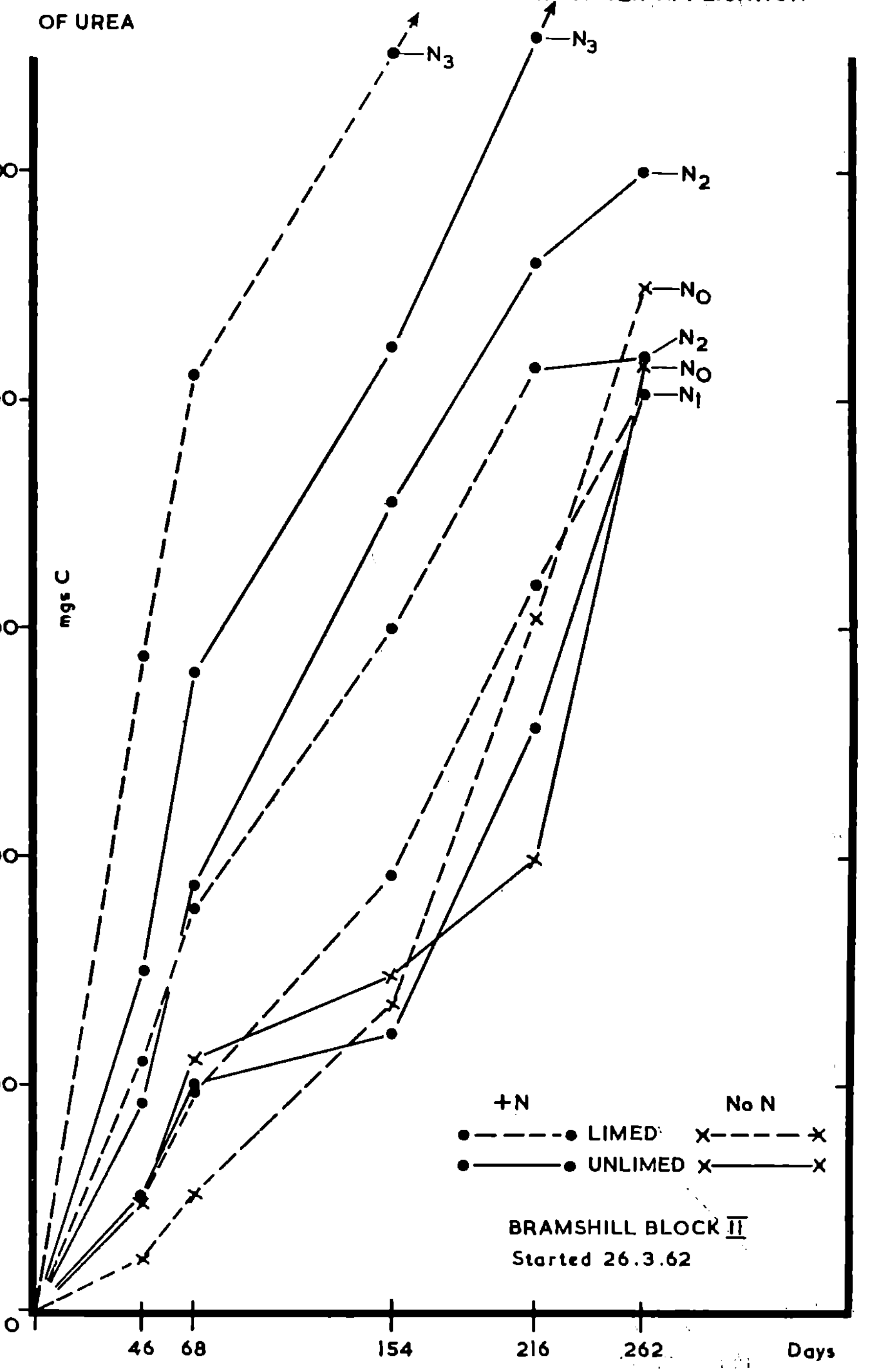

FIGURE 8. Carbon leached from Microlysimeters: After application of Urea.

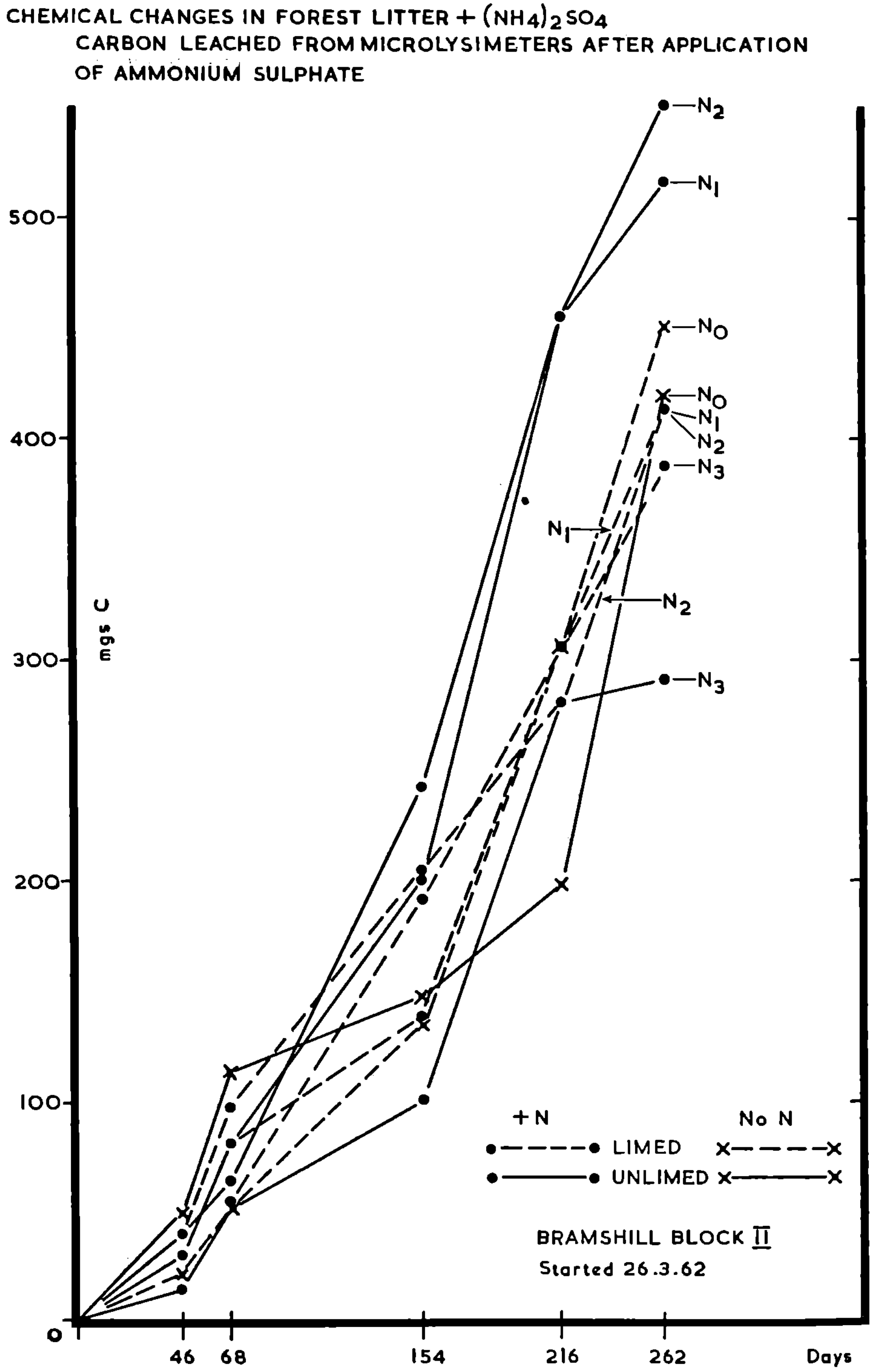

FIGURE 9. Carbon leached from Microlysimeters: After application of Ammonium sulphate.

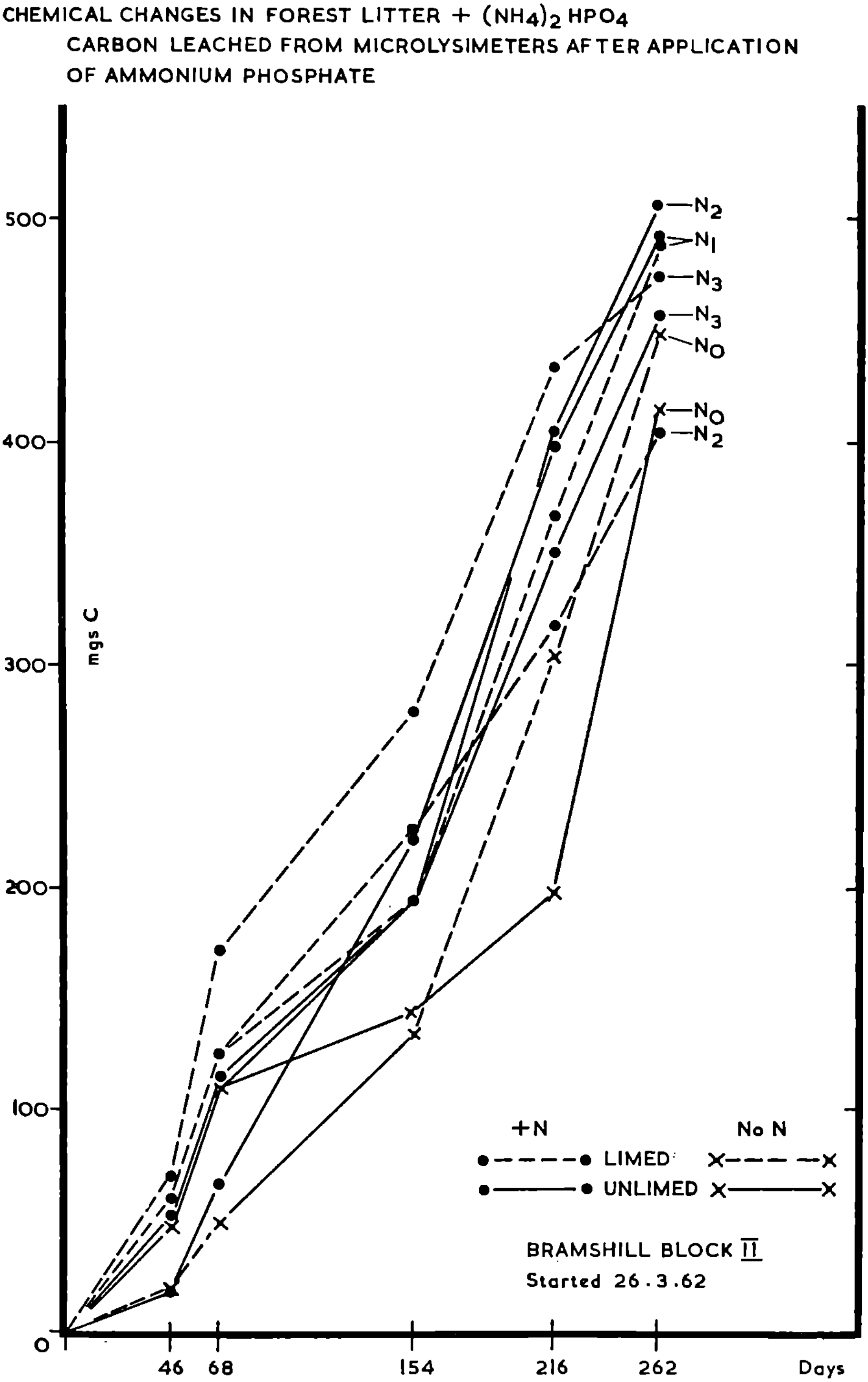

FIGURE 10. Carbon leached from Microlysimeters: After application of Ammonium phosphate.

By comparison, leachates collected from the N_3 ammonium sulphate treatments contained similar quantities of nitrogen but, as may be seen in Fig. 6, most of it was in ammonium form and the amount of organic carbon in the leachate was very small in the early stages, from both limed and unlimed soils, as may be seen from Fig. 9

Ammonium phosphate was more nearly like ammonium sulphate than urea in its effects on both the nitrogen and carbon contents of the leachates, as may be seen from Figs. 7 and 10.

Thus it appears that much of the nitrogen in organic ammonium sulphate and phosphate applied to the surface of a forest soil is readily leached through thin organic horizons, such as those at Bramshill, during the first year after application; that which is not absorbed by the roots is likely to be lost in the drainage water. However, the nitrogen in urea appears to react with the organic litter to some extent, either by direct chemical reaction or through the agency of microorganisms; some of the resulting humus compounds may be leached into the underlying mineral horizons, and so alter the distribution of organic matter in the soil profile, with the result that the turnover of the nitrogen between the soil and the tree crop may be modified. Analysis of the needles from the trees should indicate any significant changes in the nitrogen status of the trees resulting from the different forms of fertilizer.

Analysis of Leachates from Laboratory Columns

Under laboratory conditions at 18°C, urea applied at the N_3 level stimulated microbiological activity as measured by release of carbon dioxide. But if the yields are corrected for the carbon supplied in the urea then there was little difference in activity between the control columns without added nitrogen, and those receiving urea or ammonium phosphate. The most significant effect was the depression in activity produced by ammonium sulphate without lime, due to the intensely acid condition which developed in the column.

No detailed results for the nitrogen and carbon in the leachates are included here, because the trends were very similar to those found in the field lysimeters, the leachates from the urea treatments being much richer in organic carbon than those from ammonium sulphate and phosphate.

Since the form of fertilizer nitrogen affects the solubility of the organic matter, it may also affect the distribution of nutrient cations like potassium, calcium and magnesium. So it is proposed to discontinue the initial series of laboratory columns and set up a fresh series to investigate this point.

Extraction of Selected Samples with Anhydrous Formic Acid

In order to study the composition of the organic matter in more detail, samples from selected unlimed plots have been extracted with a boiling mixture of 90 per cent v/v anhydrous formic acid and 10 per cent acetylacetone. Exploratory tests showed that this reagent dissolved rather more organic matter than did the formic acid containing 0.2M lithium bromide, as used by Parsons and Tinsley (1960). The yields of dissolved organic matter recovered by precipitation with di-isopropyl ether, containing acetyl chloride to keep metal cations in solution, were not very different from different plots; on average, they amounted to 21.2 per cent of the original. The nitrogen content of this precipitated fraction was 2.65 per cent, compared with 1.45 per cent in the original;

so clearly formic acid has dissolved nitrogen-rich material. Hydrolytic studies have shown that it is also enriched in polysaccharide, for it contains about 21 per cent of reducing sugars, compared with 11.8 per cent in the original. Further work is continuing to determine the quantitative pattern of individual sugars, uronic acids, amino sugars and amino acids in materials isolated from the whole range of plot samples.

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TINSLEY, J. and HANCE, R. J. 1962. *Forest Research.*

HYDROLOGICAL RELATIONS OF FOREST STANDS

By L. LEYTON and E. R. C. REYNOLDS
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The investigation on methods for the measurement of rainfall above the forest canopy, carried out for a number of years, has now been virtually concluded; the results are being discussed in a series of papers in the *Meteorological Magazine* for 1963. Probably because of the relatively sheltered nature of the site, very little difference in catch has been demonstrated between arrays of different rain gauges fitted with different types of protective wind shield. Consistency between gauges however, provides little guidance as to their absolute accuracy and since knowledge of the latter is basic to accurate hydrological research, it is hoped that these investigations will stimulate more specialized research on this problem; the more so since evidence has been obtained of short-term differences between rainfall over the stand and that on a nearby open area where measurements have been made according to standard meteorological practice. Differences between the collection of dew by different designs of rain gauge, and that by a vegetative cover, introduce further complications in the evaluation of the water-balance of an area.

In collaboration with Mr. K. F. Wells (Russell Grimwade Scholar) and Dr. B. E. Juniper (Oxford University School of Botany), studies of the fate of precipitation intercepted by trees are being actively pursued, both in the laboratory and in the field. Measurements on potted conifer trees and shoots indicate that evaporation of intercepted water usually exceeds the simultaneous depression of transpiration, but this loss may be compensated by direct uptake of water through the foliage. In Scots pine, absorbtion has been traced to the adaxial surfaces of the needles below the top of the basal sheath; electron micrographs have revealed the absence of wax deposits on these surfaces, in contrast with the *exposed* needle surfaces; these differences are also reflected in their wetting properties. A report on these findings has been written up for publication in *Nature*. In the field, use has been made of leaf wetness recorders (kindly loaned by the Meteorological Office) to estimate the length of time the various parts of the canopy remain wet after rain. Attention has also been paid to the effect, on soil moisture relations, of the concentration of intercepted water by stem-flow and drip. Measurements have confirmed marked differences in these quantities within and between stands of different species; stem flow was negligible in European larch, but the volume per tree was considerable in Beech and Norway spruce. The results are being analyzed to see how far these differences can be attributed to particular characteristics of the trees.

A small lysimeter fitted with a porous plastic base, and subjected to a continuous suction of about 100 cm. water, offers some promise in the measurement of evaporation from the forest floor, as a measure of the difference between throughfall and drainage. A number of these lysimeters are being distributed below the stand for estimates of total soil moisture evaporation, and to see whether any patterns can be detected.

More detailed studies on drainage patterns are being made using arrays of nylon resistance units and tensiometers installed at different points between trees and at different depths in the soil. Analyses of soil moisture data collected over a two-year period await the calibration of these instruments, now being carried out.

Further improvements have been made in the method for measuring the transpiration of individual trees using the heat-flow technique. As alternatives to the radio frequency heating originally employed, heating by resistance wire wound around the stem and by alternating current passed through the stem are being tested. For the calibration in terms of absolute water loss, the original polythene bag has been replaced by one of terylene (I.C.I. Melinex). The measurement of air-flow through the bag has been improved by the introduction of Pitot tubes.

Measurements of environmental factors are being extended by the installation of a net radiometer. In order to obtain a more representative measurement, the radiometer is mounted at the end of a boom, designed to rotate continuously over the stand.

Most of the field work has been carried out in Bagley Wood, near Oxford, by courtesy of St. John's College. The routine collection of data and maintenance of the equipment has been made possible largely through the assistance of Mr. E. A. S. Ogden.

THE STUDY OF FIRE SPREAD IN FOREST FIRES

By P. H. THOMAS and D. L. SIMMS

Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization

This year fire-spread in still air has been investigated, where the most important means of heat transfer for some kinds of fuel-bed seems to be the transmission of radiation through the bed itself. A theoretical relation has been derived on this assumption.

If heat transferred ahead of a fire raises the fuel to a temperature at which volatiles are emitted in sufficient quantity to sustain a flame, the rate of spread of fire can be evaluated from a heat balance equation which, in its simplest form, may be written:

$$R\rho c\theta = Rc\,\theta\,\frac{w}{d} = Q \qquad (1)$$

where: R is the rate of spread of fire

ρ is the mean bulk density of the fuel bed

c is the specific heat of the fuel

d is the depth of the fuel bed

w is the mass of fuel per unit area of ground

θ is the temperature rise of the surface of the solid fuel necessary for ignition in the presence of flame

and: Q is the net rate of heat transfer per unit vertical cross section of the fuel bed.

Thin fuels may be regarded as heating uniformly, but with thick fuels the interior does not rise in temperature as fast as the surface, and a term involving the ratio of the surface cooling Ha to the thermal conductivity, K, has to be introduced where a is the thickness dimension. In addition, the moisture content will also affect the rate of spread of fire, so that the heat balance equation has to be expressed in the more general form:

$$\frac{R\rho c}{H} = F\left[\frac{Q}{H\theta}, \frac{Ha}{K}, M\right] \qquad (2)$$

where M is the moisture content, expressed as a percentage of the dry weight and F denotes an unspecified function.

When Ha/K is small, equation (2) reduces to equation (1), with a term for moisture content. If H, c, θ and Q are constant for a series of experiments, equation (2) states that $R\rho$ can be related to a/K and M.

The results of a number of experiments made at the Fire Research Station and by Fons (1962) to measure the rate of spread of flame along cribs of wood of various thicknesses and porosities have been used to test this relationship. The largest group of results on one species of wood is for white fir; the range of moisture contents varied from 4 to 16 per cent with a corresponding range of densities 0.3 to 0.55 g/cm^3 and stick thicknesses of 0.7 to 3.2 cm. The values of thermal conductivity were computed from its known variation with density. No numerical values of H and c are required to derive the relationship between R, a/K and M; it is only necessary to assume that they are constant.

A statistical analysis, assuming a power-law relationship for sixty tests on white fir, gives:

$$R\rho \propto (a/K)^{0.24}\ (M)^{-0.44} \qquad (3)$$

with a multiple correlation coefficient of 95 per cent.

In order to compare equation (3) with equation (2) the following assumptions must be made.

(1.) M enters into both equations (2) and (3) in the same way

(2.) $Q/H\theta$ is constant

(3.) The transfer of heat in cribs is mainly radiative. (Suitable relations for the attenuation of radiation through the fuel-bed have been obtained by measurement, and by considering scattering in matrices. The results are in reasonable agreement).

In addition, values for H and c have to be assumed and values of 8×10^{-4} cal cm^{-2} s^{-1} deg C^{-1} and 0.34 cal g^{-1} deg C^{-1} respectively have been taken.

In Figure 11 the experimental data for white fir have been plotted in terms of the dimensionless groups $\frac{Ha}{K}$ and $\frac{R\rho c}{H}\left(\frac{M}{10}\right)^{0.44}$ Through these, the best line as indicated by equation (2), has been drawn and for this the value $Q/H\theta = 6.5$ has been used. Now H and θ are known and this gives a value for Q of 1.5 cal cm^{-2} s^{-1}, which is in reasonable agreement with experimental determination.

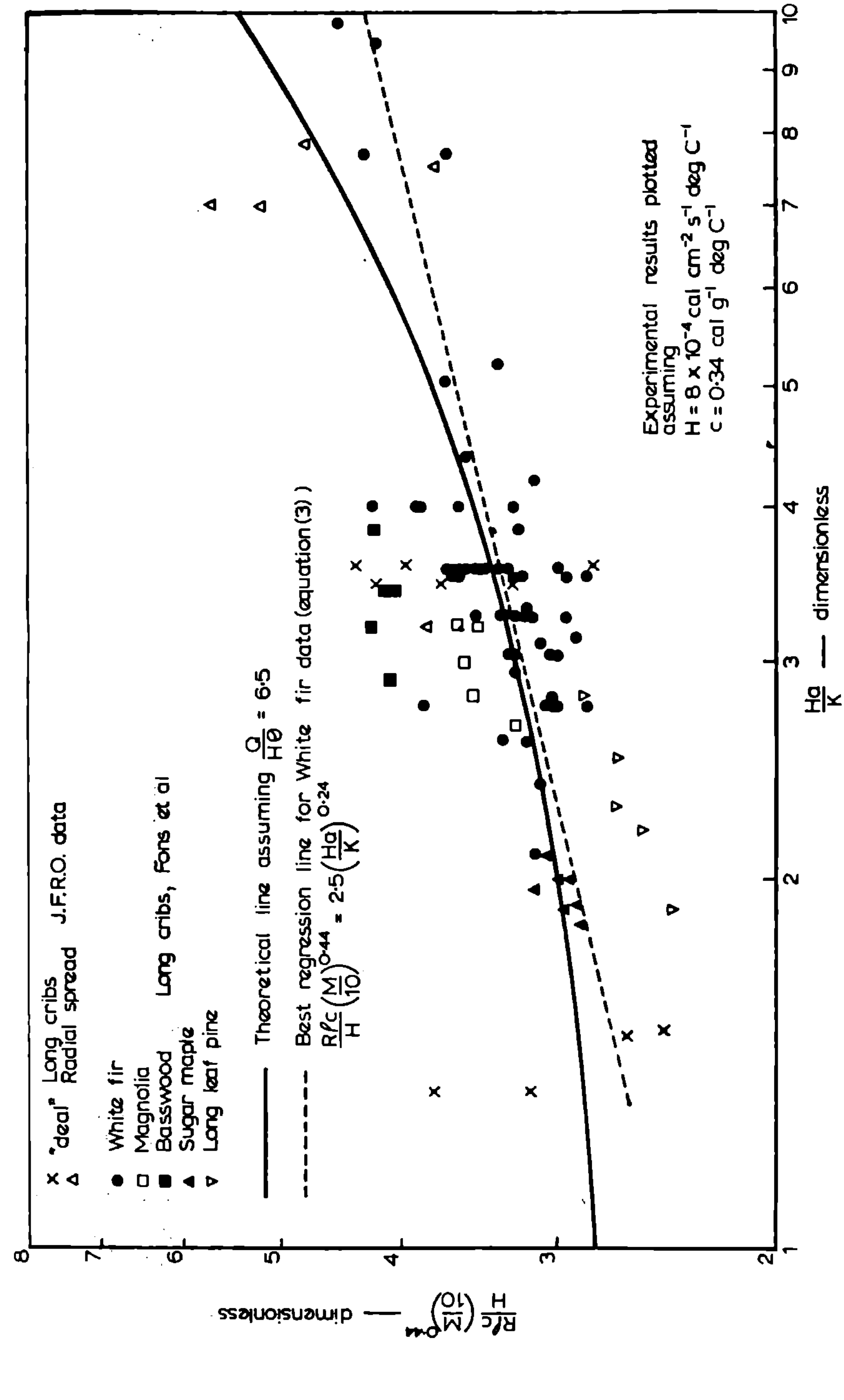

FIGURE 11. Rate of Fire Spread in Cribs of 0·7 — 3·2 cm. Wood.

Table 19

SUMMARY TABLE OF RESULTS

Experimental Fuel	Bulk density of fuel bed mg/cm^3	Effective fuel thickness $\frac{4\ \text{Volume}}{\text{surface area}}$ (a for square section)	Range of mass burning rates $R\rho$ $mg\ cm^{-2}s^{-1}$	Remarks
Cribs of square sectioned sticks—white fir, long leaf pine, magnolia, basswood, sugar maple, "deal", in beds 14–120 cm deep.	80–200	0.7–3.2	5–15	Still air. $R\rho$ increases with Q. Minimum value of $\lambda \sim 1$ cm
Wood shavings (poplar). Depth of fuel bed of order 10–15 cm.	5–40	0.04	6–40	Still air. $R\rho$ increases as ρ increases i.e. as λ decreases $0.2 < \lambda < 1$
Ponderosa pine sticks and needles. Depth of fuel bed 10–15 cm.	1–200	0.1–0.6	5–8	Still air $0.2 < \lambda < 1$ A few results for low λ or high ρ uncorrelated with others give $R\rho < 5$.
Heather (*Calluna*)	0.6–6		3–60	Winds between 90 and 360 cm/s. (7 results).

The data for the other species obtained by Fons and those obtained at the Fire Research Station (1962), including a few results for radial spread in cribs are shown in Fig. 11. The data for the other species and for radial spread are somewhat more scattered but follow the same trend.

For very thin materials, equation (2) degenerates into equation (1) and $R\rho$ should be constant and equal to $Q/c\theta$. However, from the results of experiments by Curry and Fons (1940) on radial flame spread among materials of mean thickness between 0.1 and 0.6 cm it has been found that:

$$R\rho = 8.5\ (1 - 0.36\lambda) \quad \text{mg cm}^{-2}\ \text{s}^{-1} \qquad (4)$$

where λ is the volume of voids per unit surface of solid fuel and lies in the range 0.2—0.8 cm.

This would suggest that voids in the fuel are important in controlling the rate of spread.

The result does not hold so well for wood shavings and closely packed fuels; the reasons for this difference are being investigated.

The data are summarized in Table 19. Also included for comparison are some measurements made in field trials in Exeter Forest and the Black Isle. As would be expected, the highest rates of spread are considerably higher in field trials than in the controlled laboratory experiments, because of the wind; but the lower end of the range of the rates of spread is of the same order. The table shows the relative constancy of $R\rho$ over a wide range in ρ. Consideration is now being given to obtaining more field data on the rate of spread in controlled fires, for which the value of ρ will also be obtained.

During previous years the main effort in the study of fire spread in forestry materials has been to evaluate the effect of wind on the length and orientation of the flames in order to find its effect on the heat transfer to the fuel. This work is now being used to extend the theory to include the effects of wind.

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OAK POPULATION STUDIES

By J. E. COUSENS and D. C. MALCOLM

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I. Variation of Some Important Diagnostic Characters of Quercus petraea (Matt.) Liebl. in Eire, and Quercus robur L. in Eastern England

Work to date (see Research Reports 1961 and 1962) suggests that the problem of field identification of the two oaks is unlikely to be resolved in Scotland. The Scottish data appear to indicate extensive introgression into both *petraea* and *robur* populations (*Watsonia* 5 (5) 1963, 273–286). A provisional definition of *Q. petraea* in Scotland has been published (*Scot. For.* 16 (3) 1962, 70–79): the differences from previous descriptions are not great. None of the Scottish *robur* populations was sufficiently homogeneous (in terms of the selected criteria) to justify attempting a definition of *Q. robur.*

Eire was chosen for further *petraea* collections because there are still some fairly extensive remnants of old *petraea* forests and these have had much less intensive management (with little planting) over a shorter historical period than their counterparts in England and Scotland. Details of collections made appear in Table 20. There is evidence of only a little introgression of *robur* genes into these *petraea* populations and the pattern of variation suggests that it is of long standing. A description of *Q. petraea* in Eire based on these data would agree in most details with that based on only the most homogeneous Scottish populations sampled, with one important difference—the length of peduncle to first bract is consistently shorter in the Irish collections (modal value 1 mm. as compared with 3 mm. in Scotland.) Originally, then, the *petraea* populations of Eire and Scotland may have been very similar and the difference now would lie in their rather different treatment by Man. It is suggested that the planting of introgressed *robur* in the *petraea* woodlands of Scotland initiated a new wave of introgression.

The search for homogeneous *robur* populations was continued in eastern England and on some of the heavy clays in the Midlands. Details can be found in Table 21. The results of these collections were very disappointing; for the English *robur* populations appeared to be only a little less introgressed than those in Scotland. Specimens complying with the theoretical *petraea* type in Eire comprised 70% of all samples from *petraea* populations. The corresponding figures for the theoretical *robur* type are 10% in Scottish and 17% in English *robur* populations. Furthermore it is not possible to redefine the theoretical *robur* type on a broader basis without admitting an obviously introgressive element.

Considerable local knowledge is essential for the planning of such collecting trips and I am deeply indebted to Mr. T. McEvoy and many officers of the Department of Lands, Forestry Division, for their assistance in Eire, to Dr. J. D. Ovington and numerous officers of the Nature Conservancy for their help in British Nature Reserves in England and to Dr. E. W. Jones of the Commonwealth Forestry Institute, Oxford University, who took me personally to several *robur* woods in the Oxford area.

J.E.C.

II. The Oakwood Survey in Scotland

The area selected for carrying out the pilot survey was Galloway, that is the counties of Wigtonshire and Kirkcudbright. The main reasons for this division were (1) Populations of homogeneous *Q. petraea* were known to exist. (2) A relatively heavy concentration of oak woodland occurs. (3) The area forms a distinct geographic unit. (4) There may have been less interference with the woodland than elsewhere in Scotland.

The Census of Woodlands (Forestry Commission 1952 to 1953) showed that in 1947 there was about 6,500 acres in which oak occurred as the principal species, so it was necessary to find some means of eliminating stands of definite plantation origin if the resources available were not to be wasted in investigating

Table 20

Collections made in Eire August 1962

No.	Locality	Region	Approx. Ht. a.s.l. (ft.)	No. of Specimens	Main Affinity	Hybridity Index *	Notes
1	Cree Valley—Ballycoyl	S.E.	500	21	petraea	0.52	Mainly large trees with spreading crowns seldom forming canopy—Age 150 years +
2	„ „ —Deer Park		500	23	„	0.35	Widely spaced remnants of closed forest? –now park-like—Age 200-300 years.
3	Glen o' Downs	1–6	400	13	„	0.86	Fairly young coppice regrowth
4	Glendalough—Lugduff	Wicklow Mts.	500–1000	20	„	0.35	Closed canopy woodland—worked for charcoal and timber—woodland since 9th century at least
5	Vale of Clara—Croniebyrn		400	15	„	0.40	Widely spaced large trees interplanted with conifers
6	„ „ „ „		400	12	„	1.08	Coppice regrowth recently opened up and planted with conifers
7	Shelelagh—Culliton Est.		280	17	„	0.20*m*	Closed oak woodland not derived from coppice—Age 300 yrs +?
8	Borris—Borris Est.		200	2	robur	—	Wood on a steep bank of the River Barrow
9	Portlaw—Curraghmore Est.		150	34	petraea	0.42*m*	Extensive closed oak woodland of considerable age (200–300 yrs?)
10	Glengariff	S.W.	0–100	35	„	0.39	Scrubby coppice regrowth—area worked for charcoal till about 1810
11	Kilabunane—Kenmare			1	robur	—	Self established ? in young coppice regrowth
12	Killarney—Tomies Wood		200	60	petraea	0.45*m*	Reputedly continuous history as oak wood—? part felled during Napoleonic Wars?
13	Limerick—Cratloe	W	200	15	„	0.33*m*	Fairly young coppice regrowth retained among conifers planted
14	Gort—Owendaluleegh			5	robur	2.60	Marginal remnants of oak woodland now cleared & under conifers
15	Connemara—Ballynahinch		100	19	petraea	0.35	Scrubby coppice regrowth probably c. 150 years old
16	Lough Corrib—Pontoon		100	13	„	0.20	Scrubby coppice regrowth
17	„ „ „		100	20	„	0.27	Closed canopy shore wood probably derived from coppice
18	Lough Gill—Cullendra	N.W.	50	33	„	0.30	Windblows in closed canopy wood c. 150 yrs. old and probably derived from coppice
19	Lough Eske—Ardnamona		200	32	„	0.59	Isolated large trees with coppice and rhododendrons beneath—remnants of closed woodland?

Notes—*This index is calculated from the number of observed degrees of difference from the theoretical species type divided by the number of specimens in the collection. The theoretical species type gives a value of 0 and the theoretical Fl hybrid a value of 4 (For details of the characters used see *Watsonia* 5(5) 1963 pp. 273–286). Generally a value of 0.5 or less indicates the absence of obvious introgression.

m There were a few marginal trees of robur affinity in these collections: they have been ignored in calculating the hybrid index.

Table 21

COLLECTIONS MADE IN ENGLAND JULY 1962

No.	Locality	Region	Nat. Grid Ref.	No. of Specimens	Main Affinity	Hybridity Index *	Notes
1	Castor Hanglands (N.C.)	East Anglia	TF 1101	30	robur	1.73	Mainly rather small standards in coppice
2	Monk's Wood (N.C.)		TL 2080	23	,,	1.69	West Wood—closed high canopy—considerable defoliation on the eastern margin
3	Hale's Wood (N.C.)		TL 5740	25	,,	0.88	The Oxlip Wood—closed high canopy
4	High Halston (N.C.)	Kent	TQ 7778	15	mixed	r 2.22	Closed canopy wood with many large gaps
5	,, ,, ,,		,,	14	,,	r 1.78	Coppice regrowth
6	Blean (N.C.)		TR 0245	14	,,	—x	Young coppice regrowth
7	Hoad's Wood		TQ 9841	11	robur	1.60	Spreading standards over coppice
8	Ham Street (N.C.)		TR 0134	30	petraea	0.72	Closed high canopy woodland in Compts. 5, 9 & 11
9	,, ,, ,,		,,	14	robur	—x	Miscellaneous collections of aff. robur forms
10	High Standing Hill (N.C.)	Windsor	SU 9474	14	robur	1.71	A sample from the very old trees 300 years + ?
11	Wytham Wood	Oxford	SP 4808	23	robur	1.52	Widely spaced spreading crown trees in the 1814 enclosure
12	,, ,,		,,	11	,,	2.00	More closely grown oak in the 1540 enclosure—now opened up in places
13	Waterperry (N.C.)		SP 6009	12	,,	—x	All available fruiting specimens from small coppice regrowth
14	,, —Bernwood (F.C.)		,,	24	,,	2.21	Coppice regrowth on a particularly heavy clay
15	Blenheim Palace Grounds		SP 4215	44	,,	1.84	Park-like remnants of a wood c. 300 yrs. old—gravel cap over clay
16	Weston Wood—Bicester		SP 5419	27	,,	2.00	Remnant large standards over coppice on heavy clay

Notes—* See explanatory notes beneath Table A
x Not population samples

N.C. = Nature Conservancy
F.C. = Forestry Commission

stands of no interest to the survey, the aim of which is to locate *Q. petraea* populations likely to be derived from indigenous stock.

The method adopted was to compare the current O.S. 1 inch to 1 mile (Seventh Series) sheets with Roy's map of Scotland surveyed at 1 inch to 1,000 yards between 1747 and 1756 (Royal Scottish Geographical Society 1936). All woods existing prior to 1756 and still extant were marked on the O.S. sheets. These woodlands, thus located, which still contain oak as a main or subsidiary species, were determined with the aid of the Hollerith tabulations and map photographs used to prepare the 1947 Census which were kindly lent by the Research Branch of the Forestry Commission. For each stand with oak the following data were noted; O.S. grid reference, associated species, stand area, age, stocking, form, type (e.g. High forest, Scrub, etc.) and locality name. The result of this process was:—

	Woodland Areas pre-dating 1756	*Oak present*	*Total Area* (*acs.*)
Wigtown	65	17	326
Kirkcudbright	364	153	3,354
Galloway Region	429	170	3,680

This method in addition to eliminating those woods of relatively recent origin meant that (1) the location of the stands to be examined was known precisely; (2) the extent and intensity of the systematic sampling required to establish the nature of the population could be estimated.

The field procedure consisted of initially sampling a small number of trees to give an indication of the type of population present. Where this sample showed a significant proportion of *robur* aff. individuals no further work was done. In stands of apparently homogeneous *petraea* the sample was extended systematically to provide sufficient individuals to determine the range present. These collections were preserved, recorded and graphed as described by Cousens (1962). In addition notes were made on the site, associated tree species, vegetation, origin of the stand and present utilisation.

In the period under report 35 stands extending over approximately 1500 acs. were examined and collections made in 15 stands amounting to 235 individuals. Upon analysis only 3 stands (in addition to those already known) proved to be homogeneous *petraea* populations, the remainder showing a small proportion of slightly introgressed individuals. Details for each stand are included in Table 22.

D.C.M.

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Table 22

TABLE OF PREDOMINANTLY SESSILE OAK, QUERCUS PETRAEA, WOODS IN GALLOWAY
(Includes some stands sampled in the earlier taxonomic work)

Locality name	O.S. reference and county*	Sample size (nos. of trees)	Individuals within definition of *petraea*	Origin of stand	Current land use	Remarks
Galdenoch	NX 1761 W	18	13	Old coppice	Grazing	
Low Camer Wood	NX 3772 K	15	6	Coppice	Grazed stored coppice	2 distinct populations
Glenhead	NX 4078 K		10		Forestry Commission	Collection 1960
Buchan Wood	NX 4180 K		10		Forestry Commission	Collection 1960
Garlie's Castle	NX 4269 K	23	19	Coppice/scrub	Grazed	2 collections
Penkiln Burn	NX 4369 K		8	Coppice	Grazed	Collection 1960
Cairn Garlick	NX 4470 K	31	28	Coppice/scrub	F.C. interplanted conifer	2 collections
Wood of Cree	NX 481712 K	12	12	Coppice	Stored coppice	Other parts not homogeneous
Bagbie Farm	NX 4955 K	23	22	Coppice	Young stored coppice	
Birks Wood	NX 5054 K	30	27	Old coppice and natural?	Grazed & woodland	2 collections
Kirkdale Estate	NX 5153 K	18	18	Old coppice	Woodland	Along main road
Kirkdale	NX 5153 K	12	11	Planted?	Policy woodland	Cairnholy road
Kirkdale Burn	NX 5153 K	11	9	Coppice & natural	Woodland	
Barholm Castle	NX 5252 K	20	18	Coppice	Woodland	
Oaks of Kirkconnel	NX 6759 K	22	20	Coppice	Woodland	

*W=Wigtownshire
K=Kirkcudbrightshire

PHYSIOLOGICAL STUDIES ON THE ROOTING OF CUTTINGS

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The previous report dealt primarily with the rooting responses of hardwood cuttings of *Populus* 'robusta'. It was shown that the presence of growing buds is necessary for the formation of roots by hardwood cuttings of this species. Cuttings which bear unchilled dormant buds, or from which all buds have been removed, show a very poor rooting response. The present report describes experiments on the rooting responses of leafy 'softwood' cuttings. Since it is known that young expanding leaves are particularly rich sources of auxin, it might be expected that there would be important differences between the rooting abilities of cuttings taken from actively-growing shoots and those taken from leafy shoots which had ceased extension growth and formed terminal resting buds. The following experiment was carried out to obtain information on this question.

Comparison of Rooting Ability of Actively-growing and Dormant Leafy Cuttings

A large group of plants of *P.* 'robusta' growing actively under long day conditions was used, and one-third of the plants were first transferred to short-day conditions to induce dormancy. After four weeks of short-day conditions when terminal resting-buds had been formed, the top region of each plant was taken as a cutting, and at the same time cuttings were taken from the remaining (actively-growing) plants. One-half of the latter plants were allowed to remain intact while the other half were decapitated, to remove the apical region, including young leaves. There were thus three groups of leafy cuttings, viz. (1) dormant, (2) actively-growing, and (3) decapitated. All cuttings were then placed in a mixture of peat and sand and placed under long-day conditions in growth-chambers illuminated with fluorescent tubes. The results are shown in Table 23.

Table 23

EFFECT OF DORMANCY AND DECAPITATION ON ROOTING OF CUTTINGS OF POPULUS 'ROBUSTA'

30 cuttings per treatment

Type of cuttings	Mean No. of roots per cutting	Mean No. of leaves per cutting.	Root/Leaf Number Ratio.
(1) Dormant	9.2	4.6	1.98
(2) Actively growing	8.1	4.0	2.00
(3) Decapitated	7.6	2.9	2.64

Note—In the experiments with leafy cuttings described in this report, the cuttings were taken from the tips of the current year's growth and would contain few, if any, preformed primordia. The roots developed were, therefore, initiated in response to the various treatments.

It is seen that the mean number of roots per cutting was actually greatest in the dormant cuttings and least in the decapitated ones. However, considerable leaf-fall occurred in the decapitated cuttings, and when the number of roots per unit leaf-weight was calculated for each group the mean number of roots for the dormant and active cuttings was almost identical, while the number for the decapitated group was actually higher than for the other two groups. This latter result needs confirmation, but it seems clear that dormant leafy cuttings are able to form roots as readily as actively-growing ones. Thus, in the presence of leaves it appears to be immaterial whether a cutting is actively-growing or dormant. It would seem, therefore, that mature leaves are able to supply the hormones necessary for rooting, and to replace the need for actively-expanding buds found with hardwood cuttings.

Effect of Daylength on Rooting

It has been reported previously that cuttings of certain species form more roots under long-days than under short-days, and seasonal variation in rooting ability of leafy cuttings has been ascribed to seasonal changes in daylength conditions. In the majority of woody species, including poplars, short-day conditions induce dormancy and the formation of resting-buds, whereas long-days promote extension-growth. Daylength effects on rooting might, therefore, operate either (1) by affecting the activity of the shoot-apex, or (2) by affecting hormone-production by the mature leaves, independently of any effect on growth. In order to distinguish between these two effects an experiment was carried out with cuttings from actively-growing plants of *P.* 'robusta', half of which were allowed to retain their apical regions, while the other half were decapitated. The two groups were then each further sub-divided, half being exposed to long-days and half to short-days, during the rooting period. The effects of these treatments on the rooting of the cuttings are shown in Table 24.

Table 24

EFFECT OF DECAPITATION AND DAYLENGTH ON ROOTING OF CUTTINGS OF POPULUS 'ROBUSTA'

30 cuttings per treatment

Intact Cuttings			Decapitated Cuttings		
Daylength	% Cuttings rooted	Mean No. of roots	Daylength	% Cuttings rooted	Mean No. of roots
Long Day	75.0	2.0	Long Day	87.9	2.1
Short Day	72.4	1.5	Short Day	58.6	1.4

It is seen that the percentage of cuttings which rooted, and the mean number of roots formed, was greater under long-days than under short-days in both intact and decapitated plants. (This effect of daylength has been confirmed in several other experiments.) It is, thus, clear that the daylength conditions affect the rooting of poplar cuttings independently of any effect upon extension growth. Moreover, these results explain why rooting of softwood cuttings is frequently found to be optimum in June and July, when not only is the light-intensity highest, but the natural daylengths are also longest. The results of this experiment also confirm those of the preceding experiment that the mature leaves play an important role in the rooting of softwood cuttings.

Endogenous Changes in Rooting Ability of Leafy Cuttings

In order to determine whether there are any endogenous changes in the rooting ability of poplar cuttings throughout the growing season, independent of changes in external conditions such as daylength and temperature, leafy cuttings of *P.* 'robusta' were taken on four successive dates between 20th June and 3rd September, and placed in a rooting medium under long days in growth rooms under constant conditions of illumination and temperature (20°C). It was found that there were no marked seasonal trends in the rooting of the cuttings over the period mentioned, even though the cuttings taken on 3rd September had ceased extension-growth, whereas the cuttings taken on earlier dates were actively-growing. In a further experiment there was a reduction in the rooting response of cuttings taken in late September and early October, presumably because the cuttings taken at these late dates were entering a state of "deep dormancy". Thus, it would appear that there are no progressive endogenous changes in the rooting ability throughout the growing season, at least until the shoots enter a state of dormancy in late September.

On the basis of the foregoing investigations it would seem that leafy cuttings of poplar are probably best taken in late June or July, both because the daylight conditions are then most favourable and because a long subsequent period of growth is thereby obtained.

An attempt is being made to relate the periodicity in rooting responses of both hardwood and softwood cuttings, at different times of the year, to changes in the endogenous hormones within the cuttings themselves.

Effect of Shoot Orientation on Subsequent Rooting of Hardwood Cuttings

Since it is known that the position of the shoot in relation to the gravity has marked effects upon both growth and flowering in many woody plants (*Report on Forest Research*, 1958), the possibility that gravity may affect the rooting of cuttings has been investigated with hardwood cuttings of several species. Planting the cuttings horizontally, as compared with the normal vertical position, during the rooting period had no significant effect upon the rooting responses in *P. canescens*, nor in apple.

In a further experiment the possibility was investigated that the orientation of the parent shoot during its growth period might affect the subsequent rooting of a cutting taken from it. For this purpose, certain shoots of clonal hedge plants of *P.* 'robusta' were trained horizontally during the growing season. At the end of the season matched pairs of (1) normal vertically-growing shoots and (2) horizontally-trained shoots, were taken as cuttings and after chilling were planted vertically in a rooting medium. The results are shown in Table 25. It is seen that the cuttings from vertically-grown shoots produced a greater number of roots than those from horizontally trained shoots. Thus, it would seem important to pay attention to the branch-angle of the parent shoots in selecting cutting material.

Table 25

EFFECT OF ORIENTATION OF PARENT SHOOT ON SUBSEQUENT ROOTING OF CUTTINGS

64 cuttings per treatment

Position of Parent Shoot	Mean No. of Roots
Vertical . .	3.38
Horizontal . .	1.89

THE EFFECTS OF STUMP TREATMENTS ON FUNGAL COLONIZATION OF CONIFER STUMPS

By D. PUNTER

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Results were obtained from certain experiments which had been designed to determine the effects, if any, of stump surface treatments upon colonization by way of roots. Stumps treated with nine different chemicals whose influence on surface colonization was already known, each received woody inoculum of *Fomes annosus* in one lateral root. At the end of a one-year period the distribution of fungi was recorded from all lateral roots and stump bodies. Comparison with control stumps showed that the course of root colonization was modified to a considerable extent by some surface treatments.

Some strongly anti-fungal treatments, such as nickel sulphate, creosote, and resorcinol, which had been among the most effective in preventing surface colonization, allowed particularly extensive invasion of stumps by *F. annosus* from root inoculum. Conversely, stumps treated with the much less toxic potassium permanganate or thiourea were less vulnerable to such infection. Since no treatment had been found to penetrate into roots within twelve months, it was concluded that the action was dependent upon alteration in the balance of competition. A detailed study indicated that advance of *F. annosus* from roots into the stump body was regularly arrested by *Peniophora gigantea*—or more rarely by 'blue-stain' species—growing down from the stump surface except when these fungi were completely excluded by the treatment. Moreover, the frequencies of *F. annosus* and *P. gigantea* in roots usually exhibited a distinct inverse relationship.

The balance of fungi was further complicated in some stumps by copious resin production or by zone-plate tissue formed by *F. annosus* in response to contact with the treatment. The ultimate effect of surface treatment upon *F. annosus* in roots clearly depended on a combination of these various factors.

These findings have a practical bearing on the use of stump treatments for control of root disease. In plantations where *F. annosus* is already established in root systems, treatments of high general fungitoxicity, e.g. creosote or nickel sulphate, may serve to aggravate the situation by allowing the pathogen to build up below ground. Where this danger exists, treatments such as sodium nitrite and sodium metabisulphite are to be preferred. These effectively prevented surface colonization by *F. annosus*, without being so highly fungitoxic as to exclude all its competitors.

STUDIES ON TIT AND PINE LOOPER MOTH POPULATIONS AT CULBIN FOREST

By MYLES CROOKE

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In 1962 the preliminary steps were taken into a proposed long-term study of the interaction of tit (*Parus* spp.) and Pine looper moth (*Bupalus piniarius* L.) populations in the pine plantations of Culbin Forest, Morayshire. The initial main objective of the investigation is the collection of concurrent tit and Pine looper population indices from two study plots, in one of which the density of tits will be allowed to remain at its natural and low level, and in the other of which an attempt will be made to increase the tit population, mainly by providing suitable artificial nest-sites. Predation by tits on Pine looper adults has been shown (Tinbergen, 1960) to be density-dependent even at low moth densities. This implies that tit predation may act as an effective damping mechanism on oscillations in Pine looper numbers. Comparison of the indices to be collected at Culbin, where it is known that Pine looper population densities fluctuate fairly widely and frequently, may show whether this damping effect is realised; and, if it is, whether or not it is intense enough to hinder or prevent the attainment of damaging levels of looper density.

In the year under review, activity was concentrated on four main points: the selection of the study plots, the measurement of Pine looper pupal densities in the plots, the estimation of tit numbers in the plots, and the fabrication and erection of the first series of nest-boxes.

The Study Plots

The two study plots were chosen so as to be broadly comparable in site and crop composition. Plot 1, which is scheduled to receive nest-boxes, has an area of 202 acres and comprises compartments 134, 135, 136, 137, 138, 146, and 147. The crop is predominantly Scots pine planted in 1930 and 1931. Plot 2 has an area of 197 acres and comprises compartments 112, 113, 114, 115, 119, 120, 121, and 122. It is, like Plot 1, predominantly of Scots pine but with a fair admixture of Corsican pine. It was planted mainly in 1924 and 1925 and in general the growth has been poorer than in Plot 1, so that in terms of crop height the two areas are now comparable.

Pine Looper Pupal Densities

Data on the densities of Pine looper pupae in the two plots were obtained by the usual method of collection from soil quadrats. Plot 1 was sampled by eight transects, each carrying five ¼ square yard quadrats: Plot 2 was sampled by six transects, each carrying five ¼ square yard quadrats. The mean pupal density per square yard for Plot 1 was 3.5 (range of transect means from 2.4 to 5.6 pupae per square yard): the mean pupal density per square yard for Plot 2 was 4.3 (range of transect means 0.0 to 7.2 pupae per square yard).

Tit Numbers

Only two species of tits, the Coal tit (*Parus ater*) and the Crested tit (*P. cristatus*), occur at Culbin. Estimates of the number of breeding pairs of these two species were attempted by the mapping of territories as revealed by singing males, by the location of occupied nests, and by the counting of family parties shortly after the young had left the nest.

Coal Tit. The location of singing males of this species is an easy matter since the song is distinctive and can be identified at distances of up to about a hundred yards. Records of this type of activity were made during the period 26th April to 6th June, when fifteen early morning spells of observation, each lasting about two hours, were spent in Plot 1 and twelve spells of similar duration were spent in Plot 2. Separate maps showing the location of individual singing males were prepared for each observation period. Later, these maps were combined into one master map for each plot. Interpretation of the master maps produced in this way is somewhat difficult, mainly because of the relatively few contacts made and, in particular, because of the paucity of the very valuable 'twin records' (i.e. the recording of two adjacent males singing simultaneously). The available information, however, suggests that there were four occupied territories in Plot 1 and three occupied territories in Plot 2.

The location of occupied nests was not attempted until 13th June when the services of a team of seven experienced observers were available. By this date, however, the broods had left the nests and, consequently, the nest sites could not be located.

As an alternative, and on the same date, the team walked in line through a part of each plot and counted the number of family parties encountered. In half of Plot 1 three such parties were located, and in two-thirds of Plot 2 four parties were detected. This type of count gave a higher estimate of population than that obtained by mapping territories, but it has to be remembered that nothing is known about the range and mobility of these family groups, so that no great reliance can be placed upon these figures.

To sum up, it appears that the numbers of breeding pairs of coal tits on the two plots were about equal. On the basis of mapping of territories, the number per plot was three or four pairs, whilst the detection of family groups suggested that each plot contained about six pairs. These are low densities and they contrast, for example, with Gibb's (1960) coal tit figures for an East Anglian pine plantation where on a plot of 210 acres he recorded, in different years, numbers of breeding pairs varying between 27 and 56.

Crested Tit. The data obtained for this species are much less conclusive than those for the Coal tit. In the first place, no true male song was identified in the field. This, according to Dr. Otto Henze, with whom I discussed this problem recently, is customary, and location records have to be based on sighting and on the birds' alarm calls. During the early morning rounds referred to above, only five contacts with crested tits were made in each of the plots. Mapping of these few records failed, of course, to give any indication of the location or size of occupied territories.

One occupied nest was found in each plot.

The search for family parties conducted on 13th June resulted in two parties being located in half of Plot 1 and one party being found in two-thirds of Plot 2.

It is not possible from the above to deduce any precise estimate of crested tit population density. It is clear, however, that the density is low, that it is lower than that for coal tits, and that the numbers on the two plots are not widely dissimilar.

Nest Boxes

One hundred wooden nest-boxes of the John Gibb type (Cohen, 1961) were placed in Plot 1 in September 1962. They were attached direct to the trunks of pine trees by copper nails at a height of five to six feet from the ground. They were arranged on a 10×10 grid pattern at spacings of 107 yards between lines and 90 yards within lines.

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DIEBACK DISEASE OF CORSICAN PINE

By D. J. READ

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The study of factors affecting dieback of Corsican pine *Pinus nigra* var· *calabrica*, has continued. The development of disease symptoms and the distribution of disease on individual trees in different aspects has been studied. These observations carried out in conjunction with isolation of diseased sections onto malt agar plates revealed the constant association of disease with the fungus *Brunchorstia pinea* (Karst.) v.H.=*B. destruens* Eriks. In north-facing aspects, reinoculation of this fungus into buds gives high percentages of infection compared with uninoculated controls, while in nearby south-facing aspects the percentage infected is lower.

Experimental freezing of shoots, both on trees and in the laboratory, has revealed that the increase in susceptibility to disease in trees of north-facing aspects is paralleled by a decrease in their frost-hardiness. Meteorological records taken in diseased stands through two hard winters, however, show that natural temperatures were never low enough to reach the experimentally determined frost-killing point of Corsican pine.

The possibility that peculiar microclimatic conditions were either stimulating the pathogen in north-facing aspects, or restricting its activity on south-facing slopes, was considered. While observations have revealed that high humidities and low temperatures of the north-facing slopes favour the fungus and so produce a high inoculum potential, the inoculum could be recovered from the bud scales in both aspects up to one month after inoculation.

It appears therefore that the trees in more favourable south-facing aspects acquire a greater resistance to the pathogen. Results of analyses of total reserves of assimilates have provided a possible explanation of the differing responses of trees in the two aspects to both freezing and inoculation. The buds which are most susceptible to attack by the fungus have a lower carbohydrate status than that of resistant buds. This reduction of carbohydrate reserves has been noted both in naturally suppressed buds which this fungus will readily invade, and in the large apparently healthy buds on north-facing slopes which become disease-prone in winter. Thus, while the size of the disease-prone buds indicates that they were laid down under satisfactory conditions, it appears that the peculiar climatic features of the north-facing aspect, and in particular, the absence of winter sunlight, may be responsible for metabolic disturbances and the decline of carbohydrates through respiration. As a result of such a use of reserves, a weakening of resistance to the pathogen, and a lowering of frost-hardiness together with a reduction of vigour, might occur.

Monthly analyses of levels of carbohydrate reserves will now be made throughout the year in order to attempt a correlation between assimilation, vigour and disease-resistance on the one hand, and climate on the other. By this means it should be possible to ascertain precisely the climatic limits beyond which this species cannot be successfully cultivated.

PART III
Results of Individual Investigations

THE EAST SCOTLAND SCOTS PINE PROVENANCE TRIAL OF 1952

By R. LINES

Introduction

Scots pine was one of the first species used by progressive Scottish landowners when large scale planting began in the early seventeenth century; for example it was planted by Sir Colin Campbell at Drummond Hill, Perthshire, more than three hundred years ago (Anon. 1855). This and other early plantations were certainly of native origin, but, perhaps due to the poor seed yield of many of the ancient pinewoods, seed was imported from the Continent before the end of the eighteenth century. Records were seldom kept of seed origins so that for most of the plantations made prior to 1919 it is impossible to discover whether they are of native provenance. Several of the large estates which contain natural pinewoods, such as Glentanar, Castle Grant and Ballochbuie, certainly collected seed from the native pines and established plantations which were subsequently used as seed sources. The estates outside the native pine areas such as those in Moray, Nairn and lower Deeside may well have used some seed collected from native trees but the flood of cheap imported seed, used to a large extent by the nursery trade, resulted in a mixture in the woods planted during the nineteenth century.

Interest in estate forestry reached its peak in the second half of the nineteenth century in Scotland and many famous estates had selected stands from which they collected their own seed. Unfortunately many of these were sacrificed during the First World War. Since then little Scots pine seed has been imported from abroad. From 1919 to 1955 nearly 30 per cent of all the Scots pine seed used by the Forestry Commission came from East Scotland (in passing it may be noted that 47 per cent came from Norfolk and Suffolk) and a glance at the records of seed sources shows the same names of estates constantly recurring: Altyre, Innes, Brodie, Orton, Glentanar, Ballochbuie, Pitgaveny, etc. In the later lists of seed origins large amounts are recorded from the young forests of Culbin, Teindland and Lossie, from trees largely the offspring of the earlier collections from private estates.

Steven and Carlisle (1959, pp. 4 and 229–231) have shown that the remaining area of native pine is very small and the genetic composition of any stands outside this area is liable to be a mixture of native and foreign provenance.

The Provenances

In 1951 seed was collected from about thirty selected stands in eastern Scotland. The selection, by Forestry Commission staff, was based on the good appearance and growth of the trees; many of these stands subsequently became Registered Seed Sources after rigorous inspection by the Geneticist (Matthews and McLean 1957). Twelve seed lots, chosen to represent different seed regions, were sown in a replicated nursery experiment at Teindland, Moray, in May 1952. The provenances are listed in Col. 2 of Table 26; only Ballochbuie is certainly native but Glentanar, though planted, is certainly of local stock. The Meggernie stand, and both Rannoch provenances, have much genuine native pine around them; even if the plants used were not of native stock they are almost certainly pollinated by the large amount of local pollen, so that their progeny will possess native genes. The early planting of native pine at Drummond Hill does not encourage the belief that the stand planted in 1914 in Compartment 90 was of native provenance, since it is known that foreign seed was used following Sir Colin Campbell's death. The remaining provenances are likely to be of mixed descent, and resemble "Scottish larch" in that though it is now impossible to disentangle their origins, they represent a well-tried seed source which gives satisfactory plantations over a wide part of Britain. The seed was collected from a large number of trees in each stand and is therefore a sample of the whole population rather than of a few good individuals.

Early Growth and Survival

The result of the nursery experiment at Teindland showed highly significant differences in height between provenances as one-year seedlings (Buszewicz, Edwards and Matthews 1954), see Col. 7 of Table 26. The differences in height were related to the seed weights, which in turn were affected by the elevation of the seed source. The plants were transplanted at the nearby Newton nursery in 1953, only plants with a height above 1½ in. being lined out.

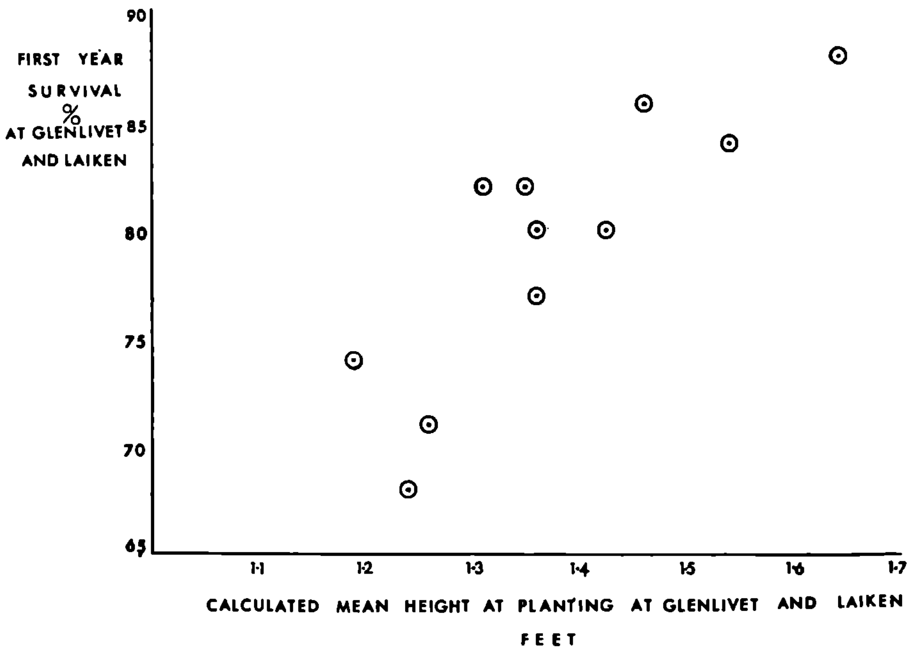

FIGURE 12. Provenance of Scots pine.
Relationship between mean height at planting and first year survival at Glenlivet and Laiken Forests, North East Scotland.

In 1954 eleven of these provenances were planted at three contrasting sites: details of which appear in Table 27. These were: Glenlivet, Banff, a severely exposed site at an elevation of 1,400 ft.; Glen Isla, Angus, a moderately exposed site at 1,270 ft.; and Laiken, Nairn, a favourable site at 300 ft. Details of the experiment sites are given in Table 27. At Glenlivet the site was ploughed at 5 ft. intervals with a tine plough; at the other two sites ploughing was not thought to be essential and was not done. No fertilizer was applied at planting, but at Glen Isla early growth proved to be so poor that in May 1957 each plant was top-dressed with 1½ oz. of ground mineral phosphate.

At Glenlivet the mean survival after one year was 82%, which can be considered good for such a testing site. The vegetation did not re-invade the furrows for two or three years, whereas at Laiken there was strong vegetation competition from the start and frequent weeding was needed. This competition was only partly responsible for the relatively poor survival of 77%, which was mainly attributable to late planting, caused by fencing delays, and to the dry early summer. At Glen Isla survival was 96%. The difference in survival between provenances at both Laiken and Glenlivet (cols. 9 and 10 of Table 26) showed a clear relationship to differences in the size at planting (Fig. 12), the larger plants surviving best. Insufficient plants were available for complete beating-up at all sites, but in all cases the central assessment plot was made good and Japanese larch was used to fill blanks in the surround rows.

Assessments of survival after three and six years show that the majority of the failures occurred in the first year and the order in rank of provenances for survival in the later assessments closely parallels that of the first. It may be inferred that there were no real differences in survival between provenances, other than those attributable to initial size of plant. Comparison of the relative survival at Glenlivet and Laiken after six years did not show better survival of the provenances from high-elevation parent stands at the high-elevation Glenlivet site, in relation to their performance at the low-elevation Laiken site, and the data are not reproduced.

Height Growth

The heights were measured at the end of the first growing season and showed the same variation between provenances as had been observed in the nursery (Col. 7, Table 26). The plants at Laiken made the best growth while at the other two sites growth was poorer and roughly equal (data not reproduced). In order to find the height at planting (which can be used as a "starting-size" for later assessments) the shoot growth was also measured and subtracted from the height after the first growing season (Col. 8, Table 26). At Glen Isla shoot growth was not measured so that the height at planting is based on the Glenlivet and Laiken data.

All three experiments made a slow start (Table 26, Cols. 11 to 13). This was expected at the severe Glenlivet site, but unexpected at Glen Isla, where growth in the experiment was slow compared with Scots pine on adjacent ploughed ground, showed the advantage of ploughing a compacted soil. Under the more favourable climatic and soil conditions at Laiken strong growth of bracken and grass slowed up the initial growth and even the tallest provenance there was less than 1 ft. in height after three years. There were highly significant differences in height at three years between the provenances, both at Glenlivet and Glen Isla. At Laiken the provenance differences were not quite significant at the 5%

level; variation in weed competition may have been responsible for reducing the precision. At all sites the order in rank for height of the provenances was substantially the same as at the first year, with Drummond Hill and Orton showing outstandingly good growth, while Rannoch (Allt-na-Bogair) and Ballindalloch were poor. These provenance differences closely follow the differences in height as one-year seedlings.

The heights after six years (Table 26, Cols. 14 to 16) again showed the superiority of the Laiken site, where the mean height had increased by 2½ ft. in three years, while the increase at Glenlivet was 1.4 ft. and at Glen Isla a mere 0.8 ft. There were no significant differences in height between provenances at Laiken and Glenlivet, but at Glen Isla there were differences at the 5 per cent level of significance, despite its slow growth and some early trouble from game birds.

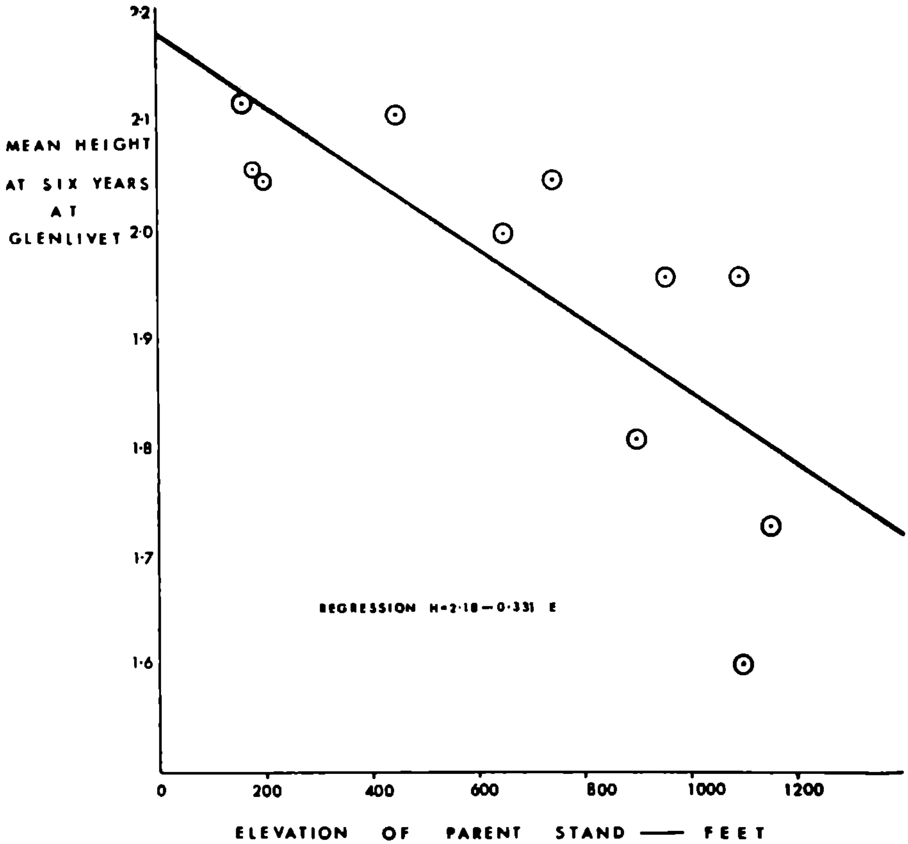

FIGURE 13. Provenance of Scots pine.
Relationship between mean height at six years and elevation of parent stand.

If the three experiments are considered as a group, the differences in height between provenances (means over all experiments) become significant at the 1 per cent level, and there was no appreciable interaction between sites and provenances. The provenances which showed the best growth at the highest site, Glenlivet, were from low-elevation parent stands (Crathes and Glentanar) while two progenies from high-elevation stands (Rannoch, Creagan-na-Corr, and Ballochbuie) showed their best growth at the low-elevation Laiken site.

Regressions were calculated for the heights at six years on the length of growing season at the parent sites (Table 26 Col. 5). Length of growing season was obtained from Anderson and Fairbairn's Bulletin (1955) interpolating for intermediate elevations in their Table 4. The most significant regression (1 per cent level) was at the severe Glenlivet site; at Glen Isla the regression was significant at the 5 per cent level, while at Laiken the regression was not significant. This would seem to imply that the correct choice of provenance is more important at high-elevation exposed sites than at more fertile ones at a low elevation.

As the length of the growing season can be expected to exert an influence on the seed weight, the data from the nursery experiment have been re-analysed to investigate this, and it was found that seed weight and length of growing season were significantly correlated. Also the regression of seedling height at one year on the length of the growing season of the parent stand was significant at one per cent.

Thus, factors such as elevation and length of growing season at the parent site influence the seed weight and the height of the one-year seedlings and are of considerable importance in explaining the difference in height at six years of age. A large part of the variation in growing season length is due to the differences in elevation, and it will be seen from Table 26 (Cols. 3 and 14–16) that provenances which had good heights at six years were largely those from lower-elevation stands in the sunny Moray Firth region, the exception being Drummond Hill, which had an unusually high seed weight for its elevation and geographical source. At Glenlivet there was a significant regression (1% level) of height at six years on the elevation of the parent seed stand, amounting to a decrease in height of 1/30th of a foot for every 100 feet increase in elevation. (See Fig. 13). The regression equation is $H=2.18-0.331\times E$, where H is tree height in feet and E is elevation in thousands of feet.

There is a considerable body of evidence (e.g. Aldrich-Blake 1937, Baldwin 1942) that large or heavy seeds tend to produce larger seedlings than small seeds, but in these cases the different sizes of seed have usually been obtained from the same source and it is therefore not unexpected that these differences in plant size do not persist for more than a few years. In the present experiment the seed weights have been shown to be largely influenced by differences in elevation and length of growing season at the parent stands, but each provenance has a different genetic constitution, influenced no doubt by the forces of natural and artificial selection operating at each parent site. The fact that early differences in seed weight are highly correlated with height of the trees at six years of age is not evidence that the seed weights are the direct cause. It is more probable that the environmental factors which influenced seed weight also operate through the genetic constitution of the provenances, resulting in greater vigour in some than in others. This theory will be tested in later assessments of this group of experiments.

Resistance to Climatic Damage

During the winter of 1959 to 1960 the trees at Glenlivet suffered from wind-lean, needle browning, death of side shoots, and snow breakage. At the other two sites damage of this kind was negligible except for wind-lean at Laiken. (See Cols. 17 and 18, Table 26).

Wind-lean was assessed as the percentage of trees leaning at more than 20° from vertical per plot and varied between provenances from 4 to 18 per cent at Glenlivet, and from 1 to 5 per cent at Laiken. An angular transformation was required for analysis. There was a significant regression of wind-lean on height, this alone accounting for the majority of the variation in wind-lean between provenances. As might be expected wind-lean was worst in the taller provenances.

Needle browning was assessed by scoring at Glenlivet on a scale 0=no browning to 3=heavy browning (Col. 19). The results showed the worst damage on Altyre and Orton, and the least on Meggernie and Ballindalloch provenances, but these differences were not significant for either provenances or replications, nor were they related to mean height. Plotting the distribution on a contour map of the site indicated a possible connection with micro-relief.

The percentage of dead shoots in the topmost whorl of the different provenances varied from 0.9 to 5.7. These differences were not significant, nor was shoot death closely correlated with height. Differences between replications were very highly significant, indicating that the variation was due to changes in slope and aspect.

Snow caused the breakage of side branches and snapping of the main stem. Only the latter was assessed and it was found to affect from 2 to 10 per cent of the trees; differences were not significant between provenances, and damage appeared to be fortuitous and unconnected with height of the tree or its topographical position.

Other Characteristics

The Laiken experiment was assessed at eight years for the percentage of trees showing present or past attack by *Evetria turionana.* This moth causes forking or distortion of the stem following loss of the leading bud or shoot (see Plate 8), but there is no "post-horn" effect such as is caused by its southern relative *E. buoliana.* Between 9 and 21 per cent of the trees were attacked in different provenances, but these differences were not significant, nor were they related to the mean plot heights at six years of age. Negligible damage from *Evetria* occurred at the other sites. (See Plate 8 in central inset).

Concurrently an assessment was made at Laiken classifying the tree stems into (1) Straight (2) Slight bend or waves, and (3) More pronounced bends and bad forks. Differences were slight and not significant at the 5 per cent level. Since one effect of the *Evetria* attack was to degrade stem form, it was thought that the provenances which were most heavily attacked by *Evetria* might have their stem form more severely affected than those which were lightly attacked, but an examination of the data did not support this hypothesis.

As the ability of a tree to produce cones abundantly from an early age is important in the formation of Seed Orchards and Seed Stands, the abundance of female cones was also assessed. While the indications were that the tallest provenance had the most cones, the number of trees bearing cones at that time was too small to give reliable data.

Conclusions

(1) Factors such as elevation and length of growing season at the parent site influence the seed weight and the height of the one-year seedlings and are of considerable importance in explaining the differences in height between provenances at six years of age.

(2) On the basis of their early growth, provenances from low-elevation stands are shown to be the most vigorous even at the high-elevation sites, but caution is needed in case later assessments show a reversal of this trend. The moderate-elevation Drummond Hill provenance has given the overall best growth and should be further tested as a seed-source, particularly to check whether the stand consistently produces seed of the same high weight as was used in this experiment.

(3) No important differences were found in early survival or climatic hardiness which were not associated with differences in height growth. Larger plants had the best early survival, but it was the taller trees which suffered the most from wind-lean.

(4) Up to six years of age, low-elevation provenances survived at least as well as, if not better than, high-elevation ones at the highest-elevation site.

(5) Only one provenance from the ancient native pinewoods is represented—Ballochbuie, a high-elevation stand which had an appreciably lower seed-weight than the others. This resulted in an initial handicap, which after six years was evident in poor height growth except at the favourable Laiken site. Glentanar is truly native, but from a low-elevation and well-treated plantation. Though the original provenances of the remaining lots is unknown, at least three are likely to have descended from native stock, while most of the others probably have a proportion of native genes in their constitution.

(6) Six years after planting, differences in height growth, as between the three experimental sites, were substantially greater than the differences between provenances at any one site.

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Table 26

HEIGHT, SURVIVAL PERCENTAGE AND OTHER CHARACTERISTICS OF SCOTS PINE

Identity Number	Provenance	Elevation feet	Climatic Region	Growing season length in days	Weight of 1000 seeds gms.	Height as 1 yr. seedlings in.	Height at planting: Glenlivet & Laiken 1/10 ft.†	Transformed* survival % after 1 yr.	
								Glenlivet	Laiken
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
52/518	Drummond Hill Forest, Compt. 90, Perthshire.	650	B2e	170	6.53	2.38	1.64	70	71
52/500	Altyre Estate, Office Wood, Morayshire.	200	B1a	186	6.46	2.26	1.42	64	63
52/493	Crathes Estate, Carleith Wood, Aberdeenshire	175	A1b	180	6.03	2.27	1.35	70	61
52/498	Orton Estate, Mill Dam & Kennels, Morayshire.	185	B1a	186	5.12	2.33	1.46	72	68
52/521	Balnaboth Estate, Angus	950	A2b	156	5.10	2.17	1.31	68	65
52/503	Ballindalloch Estate, Tomfarclas Wood, Morayshire.	900	B1a	160	4.86	2.01	1.26	59	58
52/509	Glentanar Estate, Bridge of Ess, Aberdeenshire.	450	A1b	172	4.79	2.23	1.36	72	56
52/515	Rannoch, below Creagan-na-Corr, Perthshire.	1,100	B2e	153	4.46	2.22	1.36	64	59
52/516	Meggernie Estate, by Gallin farm, Perthshire.	750	B3a	166	4.34	2.23	1.54	72	62
52/491	Rannoch, by Allt-na-Bogair, Perthshire.	1,150	B2e	151	4.30	1.97	1.24	57	56
52/511	Ballochbuie, north of private road, Aberdeenshire.	1,100	A2b	152	3.65	2.02	1.19	58	63
			Standard error ±				—	2.1	1.9
			Differences significant at % level				—	1%	5%

* Percentages converted to degrees by the usual angular transformation.

† Unit in column (8) is *one-tenth* of a foot.

PROVENANCES FROM EAST SCOTLAND

Height in feet when:						Transformed* % of trees with wind-lean at 6 years		Needle Browning Score at 6 yrs.
Planted 3 years			Planted 6 years					
Glen-livet	Glen Isla	Laiken	Glen-livet	Glen Isla	Laiken	Glenlivet	Laiken	Glenlivet
11	12	13	14	15	16	17	18	19
0.62	0.65	0.94	2.00	1.46	3.67	22.7	12.6	1.07
0.63	0.53	0.84	2.05	1.35	3.39	21.4	10.9	1.48
0.60	0.51	0.88	2.12	1.35	3.34	19.6	9.2	1.26
0.66	0.57	0.93	2.06	1.40	3.53	20.3	9.2	1.44
0.36	0.51	0.80	1.96	1.23	3.32	15.2	5.6	1.39
0.46	0.46	0.80	1.81	1.22	2.99	10.5	6.7	0.36
0.62	0.49	0.86	2.11	1.27	3.30	18.3	9.6	1.21
0.56	0.53	0.88	1.96	1.28	3.43	16.3	9.0	0.85
0.57	0.56	0.84	2.05	1.45	3.20	17.5	11.7	0.80
0.44	0.47	0.79	1.73	1.17	3.01	12.7	10.5	1.07
0.51	0.39	0.85	1.60	1.10	3.36	6.3	8.5	1.30
0.028	0.024	0.042	0.165	0.078	0.098	3.40	1.1	0.41
1%	1%	Not sig.	Not sig.	5%	Not sig.	1%	Not sig.	Not sig.

Table 27

DETAILS OF EXPERIMENTAL SITES

	Glenlivet	Glen Isla	Laiken
Map reference	NJ/158228	NO/224615	NH/906524
Elevation (ft.)	1,350–1,400	1,270	280–300
Aspect	N.N.W.–W.–S.W.	W.	S.E.
Slope	Steep	Moderate	Gentle
Geology	Slates and schists	Quartzose mica-schists.	Old Red Sandstone
Soil	Peaty podzol of heath type. Not highly developed but stony and compact.	Heath podzol overlying orange clay-loam. Compact on surface and stony below.	Brown forest soil. Clay loam with frequent stones. Formerly a high-quality larchwood site, but used as rough grazing for 30 years.
Vegetation	*Calluna* grouse moor until 1953. Burnt within last ten years.	*Calluna* grouse moor. ⅓ of area burnt just before planting. Short heather over rest of area.	Dominant bracken with *Deschampsia*, *Holcus* and herbs. Smaller area with *Calluna* dominant and scrub birch. Area invaded by gorse and broom following planting.
Climate	Anderson & Fairbairn's Climatic Sub-province B la. Length of growing season 142 days. Annual rainfall 35 in. Growing season rainfall under 15 in.	Anderson & Fairbairn's Climatic Sub-province A 2b. Length of growing season 146 days. Annual rainfall 45 in. Growing season rainfall 15-20 in.	Anderson & Fairbairn's Climatic Sub-province B la. Length of growing season 182 days. Annual rainfall 30 in. Growing season rainfall under 15 in.
Basal treatments	Notch planted at 5 × 4 ft. in bottom of tine-ploughed furrow. No fertilizer. Plot size 19 × 15 = 285 plants. Balanced incomplete block design with five replications.	Notch planted at 4½ × 4½ ft. in screefed patches. 1½ oz. GMP applied per plant in 1957. Plot size 16 × 17 = 272 plants. Balanced incomplete block design with five replications.	Notch planted at 5 × 5 ft. spacing. No ploughing or fertilizer. Plot size 15 × 15 = 225 plants. Balanced incomplete block design with five replications.

EARLY EXPERIMENTS ON THE PROVENANCE OF SITKA SPRUCE

By R. LINES

Introduction of Sitka Spruce to Britain

Sitka spruce was introduced into Britain by David Douglas in 1831, but unlike many other exotics it was not used on any scale as a plantation tree until some seventy years later. Both Loudon (1842) and Hunter (1883, p.25) refer to it as a Californian tree and Hunter notes that it "requires some shelter from cutting winds". David Douglas's seed produced very few plants and the first sizeable importation of seed was made by the Oregon Association in 1852. Thus the earliest introductions were from the southern end of the range of this species, which extends northwards to a latitude of 62° in Alaska. Prior to 1920 the Danish seed firm of J. Rafn were the principal importers of Sitka spruce seed into Europe and they obtained most of their seed from Washington (Gray's Harbor County) (Barner). Most of the older plantations formed before the establishment of the Forestry Commission in 1919 are believed to be of Washington provenance.

Forestry Commission Seed Supplies

R. L. Robinson's early experiences at Inverliever, Argyll, and elsewhere had convinced him of the usefulness of Sitka spruce for afforestation, and the newly-formed Forestry Commission purchased from the Canadian Government 3,000 lb. of seed of the 1921 crop collected in the Queen Charlotte Islands, British Columbia. This was followed by annual purchases of between 500 and 2,000 lb. of Queen Charlotte Islands seed in every year between 1924 and 1938, with the exception of 1934. In 1938 the seed supplier became the firm of C. MacFayden, but the seed source remained the same. From 1940 to 1947 MacFayden supplied seed from "British Columbia" without naming the exact provenance, though there is reason to believe that the greater part came from the Queen Charlotte Islands. Since 1947 most of the British Columbian spruce has come from the seed firms of J. B. Woods, E. G. Roche or F. E. Manning and has been almost entirely from the Queen Charlotte Islands. The great majority of the stands established by the Forestry Commission are therefore of this provenance.

Smaller but appreciable quantities of Sitka spruce seed were imported from the United States, chiefly from the state of Washington; for example 468 pounds in 1923, 596 pounds in 1926, and 655 pounds in 1935. These imports were sporadic, unlike the almost annual bulk imports from British Columbia. They reached a peak in 1947 when the demand for Sitka spruce plants for the expanded post-war programme of afforestation was high; in that year 3,467 lbs. of Sitka spruce were purchased from the U.S.A., compared with 1,391 lbs. from Canada. The following year no American seed was purchased, but 7,500 lbs. were imported from Canada. At the present time a proportion of seed from Washington is imported for use in the southern part of Britain; the earlier imports were used throughout Britain without paying particular attention to the characteristics associated with this provenance.

Continental Experience with Provenances of Sitka Spruce

In West Norway, Hagem (1931) tested forty-nine different provenances between 1915 and 1928 in a nursery near Bergen (60°N). The provenances ranged from Oregon in the south, through Washington and British Columbia, to northern Alaska. The nursery had a severe winter climate and Hagem found that only the Alaskan provenances were sufficiently hardy. "The early autumn frosts destroying the unripened shoots are believed to have been mainly responsible for the failures". Prince Rupert (54½°N) was the southernmost one to give passable results; and of the four Queen Charlotte Islands' lots, none survived the winter.

Robak (1961) analysed the results of 151 sowings of Sitka spruce in a range of Norwegian nurseries. His results show that only the north Alaskan provenances can be considered safe in nurseries in the north of Norway. Queen

Charlotte Islands provenances were unreliable, and those from further south failed to ripen their terminal buds, appearing to require a longer and warmer vegetative period. Robak points out that trees are most susceptible to frost in the nursery stage and it is possible to use provenances from southern Alaska (57°N) as far north as 68° in Norway, provided they are raised in a southern nursery. Bauger and Smitt (1960) confirm the earlier Norwegian experience, and report a plot of Alaskan provenance (Hooniah, 58°N) which grew better than a provenance from Bellakula (53°N) at Stad in Norway, 62°N.

On the mainland of Europe, Oppermann (1929) reported that in Denmark provenances as far south as British Columbia could be used. The best in his trials was from southern Alaska (Tongass, 53°N); this grew faster than the northern Alaska lots and unlike the British Columbian and Washington provenances was not checked by frost.

Karlberg (1961) stated that opinion in Denmark had changed since Oppermann's report. Severe frost damage in April 1938 was worst on the more northerly strains of Sitka spruce, and Tulstrup (1950) recommended a change to Washington provenances. Queen Charlotte Islands spruce was said to flush eight days earlier than that from Washington and to cease growth three weeks earlier. In the more rigorous climate of Northern Jutland, autumn frost damage on Washington provenances caused Queen Charlotte Islands to be the preferred source. Karlberg points out that there may be quite a variation in seed collected within the major sources (such as Queen Charlotte Islands) and he suggests that for lower rainfall areas of Europe the "slope-type" spruce is preferable to the "bottomland-type".

In Germany, Schober's trials near Hann-Münden are reported in detail (Schober, 1962). Nine provenances are included ranging from Baranof Island (56°N) through Queen Charlotte Islands, Washington and Oregon to California (42°N). The Californian provenance suffered a great many deaths during the first winter in the nursery and some plants of the Oregon provenance died. The others were fairly hardy against autumn frost, but all provenances were affected by spring frosts, greatest damage being done to the southern origins and least to the Alaskan and Queen Charlotte Islands plots. After 31 to 35 years, however, the inherently greater vigour of the Washington origins was evident in their superior height growth and volume production. The Queen Charlotte Islands provenances were nearly as tall, but their volume production was appreciably less than the Washington lots. A flushing assessment in 1956 showed that the Queen Charlotte Islands provenance flushed much earlier, while the Alaskan lot was later than the rest. The Washington and Oregon lots were intermediate in flushing date, but the sample was too small to ensure a completely reliable result. It is of interest that four of the provenances used by Schober are represented in the Welsh experiment at Radnor (No. 20), planted in 1929.

Experience in Great Britain

Previous reports of frost damage to Sitka spruce have not always shown clearly whether the damage occurred in the autumn or the spring. In the nursery death can result from either, but autumn frost is seldom sufficient to kill trees established in the forest, except for those provenances which have an inherently long vegetative period. Spring frost damage is both more obvious and more important (Peace, 1962). Edwards (1953) has summarised some early experience with Sitka spruce in nurseries, showing that Washington and Oregon provenances were more susceptible to autumn frost than those from the Queen Charlotte Islands. Steven (1928) had earlier noted that "at Oxford in the autumns of 1926 and 1927, seedlings raised from seed from Siskiyou, California, and Siuslaw, Oregon, were damaged, the terminal buds being frosted before they had ripened. In neighbouring plots, seedlings raised from seed from Queen Charlotte Islands, B.C., were not injured". These provenances are the same as those used by Schober at Hann-Münden and it is of interest to follow their later progress. The majority were planted at Radnor in 1929 and others in the forest plots at Bedgebury, Kent, and Kilmun, Argyll.

As in the German experiments, the plots at Bedgebury and Kilmun include other provenances, as follows:—

Identity No.	*Provenance*	*Year of planting*		*Similar provenance present at*	
		At Kilmun	At Bedgebury	Radnor	Hann-Münden
26/6	Olympic National For. Washington	1930		*	*
26/7	Siuslaw National For. Oregon.	1930		*	*
26/90	Queen Charlotte Is. B.C.		1931	*	*
30/43	Alaska		1933		*
30/53	Northern California		1933	*	
30/90	Alaska	1934			
30/91	British Columbia	1934			*
31/548	Murthly, Perthshire, Scotland		1934		

At Bedgebury, according to Day and Peace (1946), the frosts of late April and May 1935, when 13°F of frost were recorded on the grass thermometer, produced "very little difference between the various lots, though it is possible that those of Californian seed origin were injured rather more than those from Alaska and from Queen Charlotte Islands. Under experimental conditions, it has not proved possible to substantiate this difference, and at Bedgebury any difference was not sufficient to render the use of Californian seed undesirable on account of increased risk". The plots were destroyed in a fire in 1942. The last height measurement showed that the Californian provenance was growing faster than the Queen Charlotte Islands one and much faster than the Alaskan one. None of the provenances suffered appreciable losses at establishment.

The climate at Kilmun is very maritime and severe frost is unusual. There are no reports of frost damage to any provenance, though it was noted on April 26th, 1957 that the Washington plot had flushed when the adjacent Oregon one was dormant. Although it was in semi-check for the first five years, the Washington plot was slightly taller than the Oregon one after 31 years. There was little difference between the younger plots of Alaskan and British Columbian origin, either in height growth or in time of flushing.

By contrast with these results at the favourable Kilmun site at Corrour, Inverness-shire, (1,000 ft.) near the centre of Scotland and experiencing an almost continental type of climate with frequent severe frosts, Guillebaud (1929) observed that "differences in frost resistance of various batches of Sitka spruce are now becoming apparent. The best plants were raised from Alaskan seed .... Seed from Queen Charlotte Islands has also proved satisfactory, but other batches of more southern origin have been repeatedly frosted."

Forestry Commission Provenance Experiments

The earliest experiment was planted at Radnor Forest, Radnorshire, in 1929 and includes four provenances:

Siskiyou National Forest, California	41°50'N	124° 5'W	Elevation 230 ft.
Siuslaw National Forest, Oregon	43°44'N	124° 6'W	Elevation 150 ft.
Olympic National Forest, Washington	47°30'N	123° 40'W	Elevation 200 ft.
Queen Charlotte Islands, British Columbia, approx.	54°N	approx. 132°W	Elevation probably 0–200 ft.

The first three were samples of a few ounces supplied by the U.S. Forest Service, Portland, Oregon, and the last part of a consignment of 1,182 lbs. supplied by the Canadian Government. The Radnor plants were raised at Kennington Nursery near Oxford, where as noted above, the southern origins were damaged by autumn frost. As a result, the plants were sorted into two classes (Grade I and "Culls"), the latter class being used to greater or lesser extent depending on the numbers available. 20% of the plants in the Washington and Queen Charlotte Islands plots were "Culls", 68% were "Culls" in the Oregon plot and 85% were "Culls" in the Californian plot. The plots vary in size from 0.16 to 0.61 of an acre and are not replicated. The experiment is situated in a fairly sheltered valley on a moderate easterly slope at an elevation of 1,200 feet. Rainfall is about 50 inches and the soil is a fairly fertile Brown Forest soil, which is freely drained. The lower parts of the Washington and Queen Charlotte Islands plots, which lie below the other two, had a bracken vegetation type at planting, while the rest of the site was *Agrostis/Holcus* grass type on land which had been ploughed many years before.

Early reports show that the provenances from Oregon and California were still in active growth as late as September or October, whereas the Washington and Queen Charlotte Islands ones had formed terminal buds. The "Culls" suffered more from frost than the Grade I plants and this resulted in very open stocking in the provenances which had the most "Culls" at planting. Damage, presumably from autumn frost, was noted each February for several years and the notorious spring frosts of May 1935 caused severe damage to the lateral shoots of all provenances; fortunately few trees had expanded their terminal buds at that time. *Neomyzaphis* attack was severe, particularly on the Queen Charlotte Islands provenance.

By 1938 the trees were above the danger level from ground frost and in the Washington provenance were closing canopy. The Queen Charlotte Islands plot had an average height of 6 ft. and the remaining provenances were 2½ feet taller. The experiment was badly damaged by a glazed frost in February 1940, the worst damage, in the form of broken tops and leaders, occurring on the sparsely-stocked Oregon and Californian provenances.

Drought cracks caused by the dry August of the previous year appeared in spring 1948 (Day, 1954 p.6). In the Oregon provenance 30% of the trees showed cracks, 10% of the Californian trees had cracks and the Washington and Queen Charlotte Islands lots had 3% and 2% respectively with cracks. It was clear that the worst cracking was on trees with the largest girth, so that the open stocking and consequent greater girth of the Oregon provenance was probably a part cause of its greater susceptibility to drought crack.

In November 1955 samples of thinnings were taken for examination by the Forest Products Research Laboratory (F.P.R.L., 1958 and Wood and Lines, 1959). The timber from the Queen Charlotte Islands plot proved markedly denser than that from the others, and the strength properties usually associated with density of timber were also found to be higher in this lot than in the other three provenances. There was an indication that the percentage of dense summer wood was positively correlated with latitude, which may partly explain the higher average density of the timber from this northern origin.

The latest assessment in August 1962 (age 34 years) showed the following figures, all per acre:—

Provenance	*Number of stems*	*Average height of 100 largest trees* ft.	*Basal area* Sq. ft.	*Estimated standing Volume* H.ft.	*Estimated Total Volume** H.ft.
Siskiyou, California	151	76.3	82.6	2,800	6,670
Siuslaw, Oregon	134	85.5	101.2	3,850	6,610
Olympic, Washington	167	70.5	71.5	2,250	5,480
Queen Charlotte Is., B.C.	232	66.0	89.1	2,500	5,030

Note:—* There is no record of the volume removed in the first thinning.

Bearing in mind the poor initial stocking of the Oregon and Californian provenances, their total volume production is remarkable, though as the plots are unreplicated, the figures must be regarded with caution. The standing volumes were estimated using alignment charts which are based on calculated rather than actual form factors.

Other Sitka spruce provenance experiments were planted at Leanachan, Inverness-shire, from 1933 to 1939; Kielder, Northumberland, from 1936 to 1938; and Newcastleton, Roxburghshire, from 1938 to 1941. They have been subject to many disasters; in particular, fire totally destroyed the Kielder experiments when they were ten to twelve years old. At Leanachan many plots were burnt in 1936 and others in 1942 and the survivors were affected for several years by fluorine fumes from an aluminium works, as well as by repeated frosts. At Newcastleton, heavy frost damage killed 40% of the trees in the spring of 1945 and caused extensive shoot dieback on surviving trees. Altogether they are an unsatisfactory collection of experiments for our major species, and the gap has only recently been filled by the experiments planted in 1950 (almost all Washington provenances) and the comprehensive new series planted in 1960–61. The results of these later experiments will form the subject of a separate report.

Leanachan, Experiment 1

1937 *Section.*

A replicated experiment with plots of thirty plants, part on a bracken slope and the other in a frost hollow.

Provenances:	Masset, Queen Charlotte Islands.	54°N
	Skidegate „ „ „	53¼°N
	Cape Flattery, Olympic Peninsula, Washington.	48¼°N
	Clallam County, Olympic Peninsula, Washington.	48°N
	Washington (reputed)	—
	Flensburg, Schleswig-Holstein, Germany.	54¾°N

The plants were similar in size at planting and all provenances established well with no difference between the ones on the bracken slope and those in the frost hollow. After sixteen years Cape Flattery was tallest, followed by Flensburg and Washington, and the two Queen Charlotte Islands provenances and Clallam were the shortest. At twenty years the order in rank of the provenances was very similar, the mean height of the two Queen Charlotte Islands lots being 11.8 ft. and that of the three Washington lots 13.3 ft. Differences were not significant, partly because the statistical design is poor.

1938 *Section*

This consists of two provenances; Skidegate, Queen Charlotte Islands and Olympic Peninsula, Washington, replicated twice. The Skidegate plants were older at planting and they had better survival after fifteen years. The mean height was very similar in both provenances after twenty years.

1939 *Section*

A replicated experiment with plots of thirty plants arranged in three blocks on a *Molinia/Myrica* vegetation type and with another three on a *Calluna*/grass type.

Provenances:	Kitimat, British Columbia	54°N
	Bellakula, British Columbia	52½°N
	Alert Bay, Cormorant Island, British Columbia.	50½°N
	Campbell Lake, Vancouver Island, British Columbia.	50°N
	Olympic Peninsula, Washington.	48°N

Survival in November 1939 was excellent; severe frosts and air pollution later took their toll. After twenty years Bellakula had outstandingly good survival at 80 per cent, the other northern provenance, Kitimat, was next best (62 per cent); the Olympic Peninsula provenance had 58 per cent survival, and the Vancouver Island provenances slightly less. Survival was similar on both vegetation types. Mean height of the British Columbian provenances was 12.1 ft.

and that of the Washington provenance was 15.1 ft. after twenty years, but there was a large variation in height due to the vegetation type and as a result the differences due to provenance did not prove significant. Growth on the *Molinia* type was nearly double that on the *Calluna*/grass type.

Kielder, Experiment 29

1936 *Section*

This consisted of four provenances replicated twice in scattered plots of unequal size.

Provenances:	Flensburg, Schleswig-Holstein, Germany.	54¾°N
	Masset, Queen Charlotte Islands	54°N
	Skidegate „ „ „	53¼°N
	Comox, Vancouver Island, British Columbia.	49½°N

At the time of the fire in March, 1948, the mean heights were; Masset 8.0 ft., Skidegate 7.5 ft., Comox 7.3 ft. and Flensburg 6.3 ft. The Flensburg plants were one year younger when planted and suffered from spring frosts in 1936 and 1938 and autumn frosts in 1937, while the other provenances were little affected. It is probable that they originally came from Washington,

1937 *Section*

Three lots alternate with plots of a fourth "standard" lot from Skidegate, Queen Charlotte Islands.

Provenances:	Skidegate, Queen Charlotte Islands.	53¼°N
	Flensburg, Schleswig-Holstein, Germany.	54¾°N
	Clallam County, Washington	48°N
	Japan (original provenance unknown)	—

In March 1948 at eleven years of age, the Flensburg provenance (8.1. ft) was appreciably taller than the rest. Clallam, Washington, with a mean height of 6.0 ft. was slightly taller than Skidegate (5.5 ft.), when all plots of the latter are included, but as the site varies it is better to include only adjacent pairs of plots of these two provenances, and when this is done they had the same mean height.

1938 *Section*

Five provenances replicated one to three times in a pseudo-Latin Square.

Provenances:	Campbell Lake, Vancouver Island	50°N
	Olympic Peninsula, Washington	48°N
	Masset, Queen Charlotte Islands	53¾°N
	Queen Charlotte Islands (General Collection)	53°–54°N

At ten years old, measured after the fire, the Queen Charlotte Islands and Washington provenances were similar in height, except for the Queen Charlotte Islands general collection which were smaller at planting and had not caught up. Campbell Lake was appreciably poorer.

The results at Kielder may be summed up as follows: the rate of growth of Queen Charlotte Islands provenances is similar to those from Olympic Peninsula, Washington, while Vancouver Island provenances are inferior. Survival was generally good. Frost damage was frequent in the early years; Flensburg suffered worst in the 1936 section, but plants of the same seed lot were not worse affected than the other provenances in the 1937 section.

Newcastleton, Experiment 5

This experiment was planted on a *Molinia*-covered terrace which proved to be a frost shelf. Very severe frosting on 26th April and 29th May 1945 affected over 100 acres in Newcastleton forest and trees up to seven feet high were killed. Others were so badly affected that they died back two to three feet. Severe frost in May 1946 again damaged the experiment.

1938 *Section*

This is the main experiment with five replications of eight seed lots, including five distinct provenances, plus large unreplicated plots.

		Age and Type of plant	*Latitude*
Provenances:	Skidegate, Queen Charlotte Islands	(2+1+1)	53¼°N
	Skidegate, Queen Charlotte Islands	(2+1+1+1)	53¼°N
	Skidegate, Queen Charlotte Islands	(1+1+1)	53¼°N
	Masset, Queen Charlotte Islands	(1+1+1)	54°N
	Washington (reputed)	(2+1+1)	—
	Cape Flattery, Olympic Peninsula, Washington.	(2+1+1)	48¼°N
	Olympic Peninsula, Washington	(2+1)	48°N
	Olympic Peninsula, Washington	(1+1)	48½°N

Unlike most of the other experiments (where the age and type at planting was roughly similar) in this case there was a variation in age between five and two years. Early survivals were very good, except for the small 1+1 plants which had 30 per cent failures in the first year and 44 per cent failures by the sixth year, the remainder then having less than 10 per cent failures. Since the poor survival of this lot was linked with low height, this provenance has been omitted from the following results.

At six years the mean height of the Washington provenances was 5.0 ft. and that of the Queen Charlotte Islands ones 4.7 ft. Severe frost on April 26th, 1945 killed nearly 50 per cent of the Washington plants and nearly 30 per cent of the Queen Charlotte Islands ones; the majority of the plants showed some dieback of leaders. An assessment after nine years showed that the mean heights were less than those three years earlier, being 4.7 ft. for the Washington lots and 4.5 ft. for the Queen Charlotte Islands lots. At sixteen years of age, the mean height of the Washington provenances was 12.3 ft. (ranging from 11.6 to 13.0 ft.), that of the Queen Charlotte Islands provenances was 10.7 ft. (ranging from 9.3 to 11.9 ft.).

Flushing was assessed in the 1938 Section at periodic intervals during the spring of 1954. At the mid-flushing stage there was a difference of about six days between the earliest and latest provenances. The earliest one was from Queen Charlotte Islands, while the last one to flush was also from this origin. The Washington provenances showed less variation and, though they were in general later flushing, the differences between the two main provenance groups was not of practical importance. It is likely that some of the early-flushing individuals in all provenances were killed by the 1945 frost.

1940 *Section*

This consists of three British Columbian provenances and is incompletely replicated.

Provenances:	Alert Bay, Vancouver Island.	50½°N
	Campbell Lake, Vancouver Island.	50°N
	Kitimat, Northern British Columbia.	54°N

Alert Bay grew much faster than the other Vancouver Island provenance from Campbell Lake, but as it is represented only by a single plot, this could be due to site variation. The northern provenance from Kitimat has grown slowly.

CONCLUSIONS

The experiments have not shown a very clear pattern, as some of the results in one experiment are contradicted by those in another, but in general they do show that the Washington provenances were usually slightly superior in height growth to those from Queen Charlotte Islands, while those from Vancouver Island and the fiords of the British Columbian coast (Kitimat and Bellakula) were the poorest for height growth. Survival was perhaps slightly better for Queen Charlotte Islands than for Washington origins. Large plants proved better than small ones, and the inconclusive results are partly attributable to differences in age and type of the plants used. For volume production, which can only be measured in the oldest experiment at Radnor, the U.S. provenances were clearly superior to the Queen Charlotte Islands one. The German experiments confirm this result and show a cline for increased vigour with decrease in latitude. The Norwegian experiments show that only the far northern provenances can survive near Bergen which is on the same parallel of latitude as Shetland.

Damage from spring frosts appears to affect both northern and southern provenances to a similar degree, though the Washington lots had greater failures after the frost at Newcastleton. Little variation in time of flushing has been observed in these experiments, and individual trees within a provenance can show as much variation as there is between provenance means. Autumn frosts are the main danger to Washington and Oregon provenances, which continue growth into the autumn and they also rule out the Californian ones for wide scale use. For the southern part of Britain, there are good reasons for using the somewhat faster-growing Washington provenances, particularly those from the west side of the Olympic Peninsula, where this species is at its optimum.

In the northern part of Britain there is a choice between the well-proven Queen Charlotte Islands provenances (the other place in the natural range where Sitka spruce shows its maximum development) or the rather more frost-susceptible Washington provenances, which are potentially capable of giving a bigger volume production. There is no evidence that either will be more susceptible to diseases or pests such as *Neomyzaphis*. Alaskan provenances are not represented in the older experiments, except at Kilmun, though they are under test in the newer experiments. Their use is likely to be restricted to the north of Scotland and to difficult high elevation sites; though they might have a place in the lower-rainfall areas, where the provenances commonly used at present are showing poor growth.

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SURVIVAL AND GROWTH OF UNDERCUT SEEDLINGS IN THE NURSERY AND FOREST

By J. ATTERSON

Introduction

In Britain, past experience has generally shown that transplants are more successful than seedlings when planted in the forest. Seedlings left undisturbed in a nursery seedbed for several seasons develop a deep root system which is severely damaged during lifting operations. When seedlings are transplanted after one or two growing seasons, vertical rooting is restricted and lateral root growth produces a fibrous root system (see Plate 7 in central inset). Undercutting the seedling roots *in situ* after one to two growing seasons also restricts vertical rooting and encourages stronger lateral root development.

Undercutting has long been considered a substitute for transplanting (Schlich 1904). A number of investigators have shown that undercutting can produce plants which are sturdy enough to survive as well as a transplant e.g. Hastings (1923), Shoulders (1960). Hastings also claimed that undercutting produced the cheaper plant, but others (Kummel *et al*, (1944)) have considered that the cost of maintaining the necessarily greater sowing area and the poor control of plant density in undercutting offset the extra costs of transplanting. Although undercutting had become an established practice in many parts of North America by 1950, it has not completely replaced transplanting and the question has remained under investigation, e.g by Gingerlich and Hertel (1962) who showed that there were no significant differences in root or top weights between transplants and undercut seedlings of Austrian pine (*Pinus nigra*), but that both were more vigorous and have a root weight/top weight ratio closer to unity than uncut seedlings.

Between 1951 and 1958 the Forestry Commission Research Branch carried out some 40 experiments to determine the effect on survival and growth in the nursery and in the forest of undercutting seedlings of tree species. In Scotland, the main species used in these experiments were Scots pine (*Pinus sylvestris*) and Japanese larch (*Larix leptolepis*), and in England, Corsican pine (*Pinus nigra* var. *calabrica*), and Douglas fir (*Pseudotsuga taxifolia*). A few experiments were also carried out on Sitka spruce (*Picea sitchensis*), oak (*Quercus petraea* and *Quercus robur*), beech (*Fagus sylvatica*) and sycamore (*Acer pseudoplatanus*). Nine nurseries were used, ranging from Newton in Morayshire to Bramshill in Hampshire. The forest stage of the experiments ('extensions') was carried out in 24 forests, under conditions of cultivation normal to the site and the species. On most sites the ground had been ploughed.

Experimental Method and Design

The nursery experiments were carried out on 3 ft. 6in. wide seedbeds raised a few inches above the alleys. Some experiments were sown on soil partially sterilized with formalin or chloropicrin. Undercutting was effected with the "Blair Atholl" undercutter which is a tractor-drawn, sledge-type implement with a narrow "V" blade held by three struts capable of undercutting at very precise depths. A photograph of this implement was published by Shaw (1956), and an account of a preliminary trial was published in 1953 by Faulkner.

The nursery experiments usually took the form of three or four randomized blocks of factorial combinations of depths and dates of undercutting with plots split for plant density and/or method of sowing (broadcast or drill). In most experiments, seedlings were undercut once and were lifted for planting-out when two years old (referred to as "1 u 1", i.e. one-undercut-one). Control treatments to produce 1+1 transplants (i.e. transplanted at the beginning of the second year) and 2+0 seedlings (i.e. not undercut) were always included. Depths of undercutting were 2, 4 and 6 in. for conifers, and 3 and 6 in. for broadleaved species. Dates of undercutting varied slightly, but were generally July or August in the first year and March, April, May, June and July in the second year. Three plant densities were usually included—normal, half-normal and quarter-normal. 'Normal' densities varied with species and were calculated according to the data for two-year seedling production given on p. 4 of *Forestry Practice*, Bulletin No. 14 (Forestry Commission, 1958).

Most of the Scottish experiments were sown at the standard seed density and thinned at the end of the first year to exact densities of 16, 32 or 48 plants per square foot by cutting off unwanted plants at the root collar. All other experiments were sown at different seed densities calculated to give the correct number of plants per square foot. The second method gave densities which were less precise but acceptable. Where seedlings were drill-sown, lateral root-pruning was combined with undercutting. Lateral root-pruning was done using vertical knives mounted on a tractor tool-bar, one knife being mounted mid-way between each pair of rows of seedlings, or by hand, using sharpened garden spades.

The nursery experiments were 'extended' into the forest by lifting plants at random from treatment plots until the required number had been obtained. No culling was carried out except in the rare cases where seedlings were obviously the result of second year germination. Where possible each nursery block was kept as a block in the forest, but all treatments were re-randomized within blocks, i.e. the nursery split-plot design was not retained. The size of treatment plots in the forest varied from 24 to 42 plants; in Scotland single-line plots were generally used, but in some cases (and in all the English experiments) the arrangement was in square or rectangular plots.

When the plants were ready for lifting in the nursery, assessments were made of plant numbers, height, and root collar diameter; root and top weights, and root fibre, were assessed after lifting. Root length was not measured as it was impossible to determine whether a root had been growing vertically or horizontally after the plant had been lifted. Instead, by counting the number of secondary roots (either over 1 in. or 2 in. in length), it was hoped that differences between long root systems and compact, fibrous root systems would be distinguished. The results of all these assessments are shown in Fig. 14d under the term "Total Root Fibre".

In the forest, height and root collar diameter were measured immediately after planting. At the end of the first growing season, survival was assessed. After two growing seasons, shoot length (two seasons) and root collar diameter were assessed. Height and survival were assessed after the third growing season, and height again after the sixth growing season.

Results : Nursery Stage

(a). Numbers of surviving plants

In general, date and depth of undercutting had no effect on survival, nor had method of sowing (i.e. drill v. broadcast). Of all the species tested, only Corsican pine at Markham Oak Nursery, Hants. showed significant losses; but only when undercutting had been done at a depth of 2 in. compared with undercutting at 4 in. and 6 in. This loss was approximately 45 per cent.

(b). Height

Almost invariably, 2+0 seedlings were taller than the comparable transplants or undercut seedlings. Usually transplanting restricted height growth nore than undercutting, but this was not the case with Douglas fir and certain hardwoods. Whilst many of the differences in height growth were significant, the mean difference in height growth over all experiments between 2+0 seedlings and 1+1 transplants was only about 20 per cent. (See Fig. 14a). Very few significant interactions were found between undercutting and the other treatments (sowing method and seedbed density), or between dates and depth of undercutting. Depth had no significant effect on height growth at all. It is worth noting, however, that the lowest seedbed densities usually produced the tallest plants in all species except Corsican pine, in which species seedbed density did not affect height. Dates of undercutting usually produced very significant height differences, but these were far from consistent between experiments, although there was some suggestion that undercutting in June and July of the second year produced the tallest, and in August of the first year, the smallest two-year old plants; and in pines this was no doubt due to the fact that height growth ceases in July.

In general, therefore, transplanting and undercutting retarded height growth to a small degree, the former more so, and this result was not influenced by plant densities or methods of sowing.

(c). Top Weight

Top weight was affected by the treatments in the same way as height, but the differences between 1+1, 1 u 1 and 2+0 plants were greater. The average *reduction* in top weight caused by transplanting was about 60 per cent and by undercutting 30 per cent. In Fig. 14b it will be seen that in three experiments the transplants had a larger top weight than seedlings or undercut plants. These three exceptional cases all concern Japanese larch, but other experiments with this species conformed to the usual pattern.

(d). Root Weight

Root Weight, i.e. the weight of roots actually lifted, in contrast to topweight, was *increased* by transplanting by about 60 per cent, and by undercutting by 20 per cent (see Fig. 14c). Other treatments affected root weight in the same way as they affected height. Root fibre (as defined on page 148), as with root weight, was increased by transplanting by about 40 per cent, but by less than 10 per cent by undercutting (see Fig. 14d).

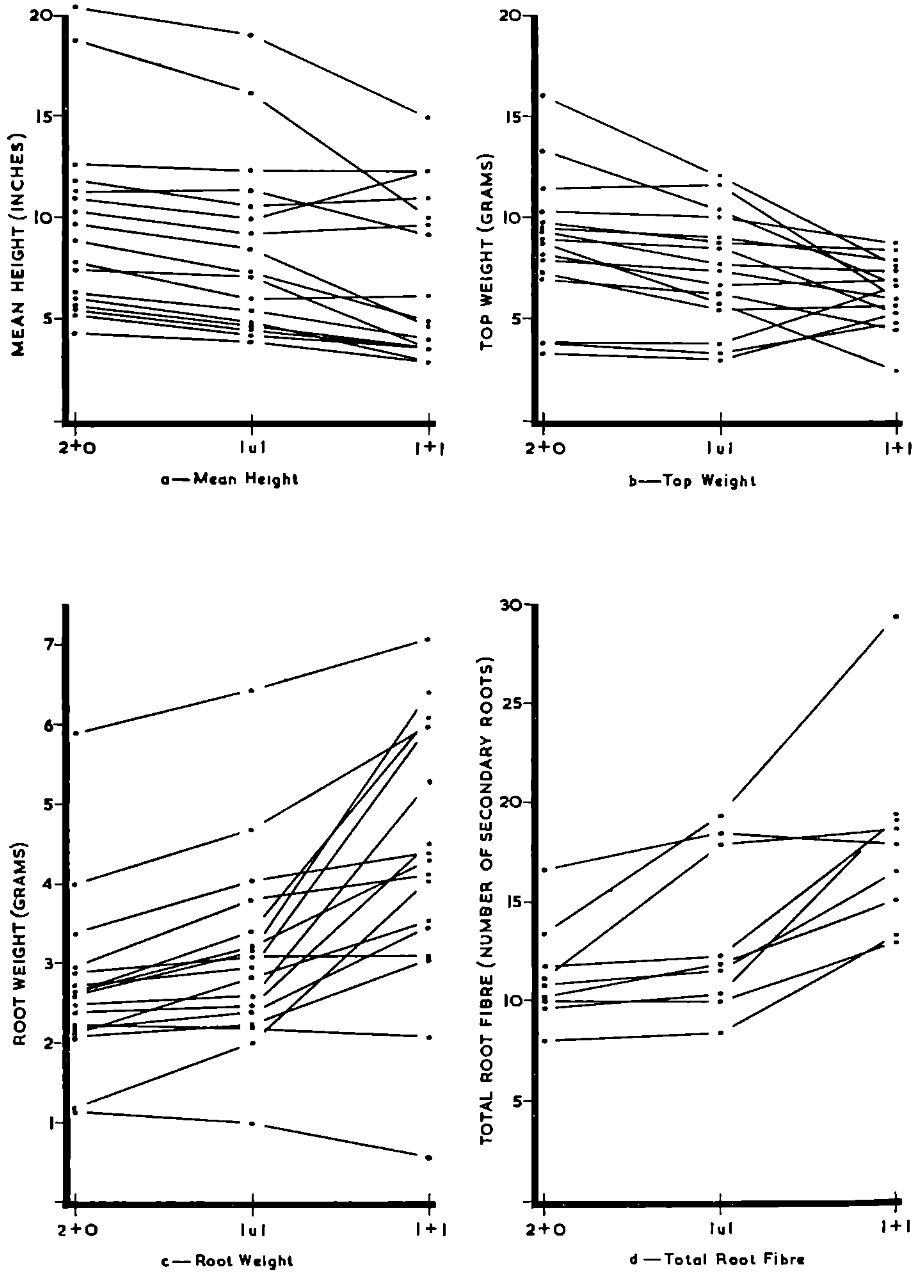
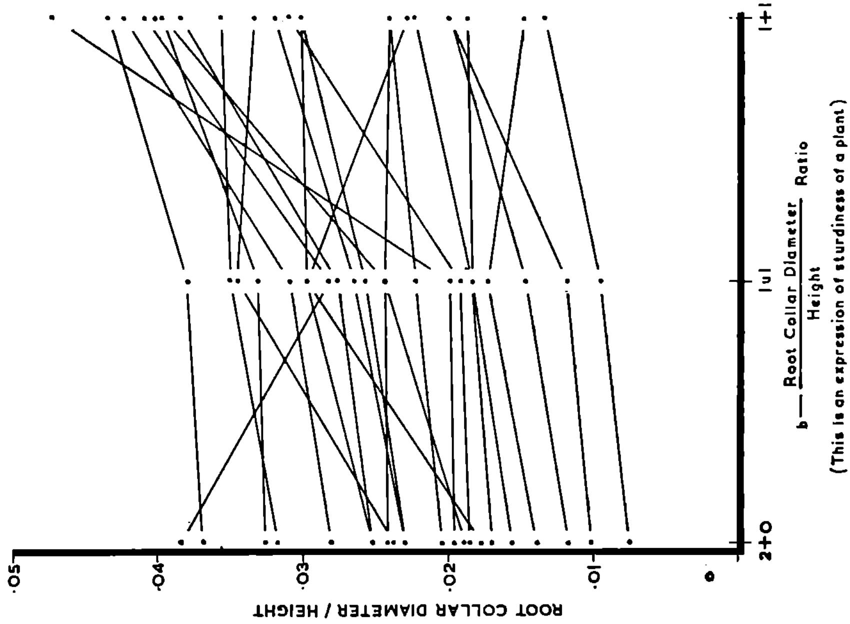


FIGURE 14 Measurements of (a) Mean Height, (b) Top Weight, (c) Root Weight and (d) Total Root Fibre, taken at two years of age from:— untreated seedlings (2 + 0); seedlings undercut when one year old (1 u 1); and transplants lined out as one year old seedlings (1 + 1). Species: Scots pine, Lodgepole pine and Japanese larch. Each line represents the means of one experiment.



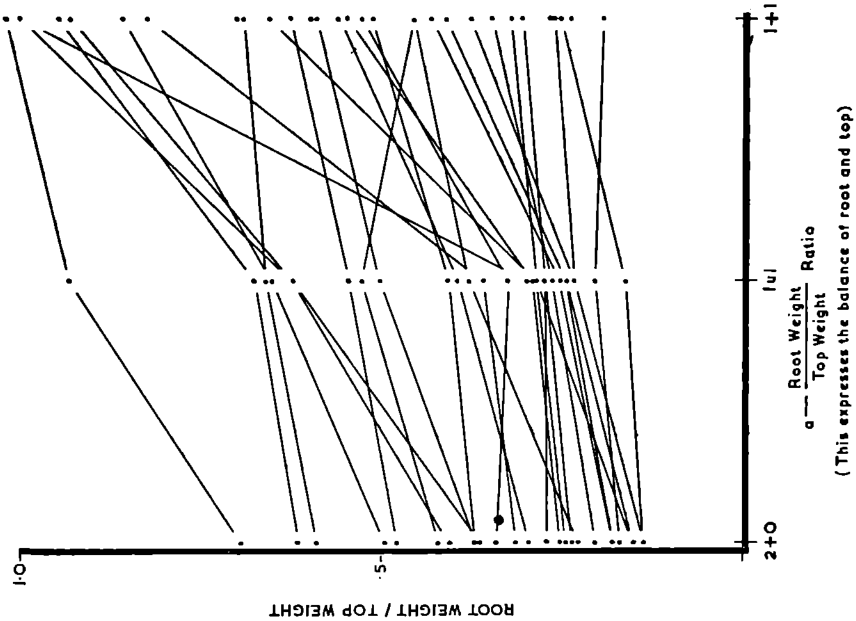


FIGURE 15. Balance (left) and sturdiness (right) of:— Two year old untreated seedlings (2 + 0); seedlings undercut when one year old (1 u 1); and transplants lined out as one-year seedlings (1 + 1). Species: Scots pine, Lodgepole pine, Corsican pine, Japanese larch, Douglas fir and Sitka spruce. Each line represents the means of one experiment.

(e). Root Weight/Top Weight Ratios

The range in root/top ratios was very large (0.15–1.0), but usually, undercutting and transplanting, particularly the latter, increased the ratio (see Fig. 15a). This confirms the common idea that a transplant is a "better balanced" plant than a seedling.

(f). Root Collar Diameter

Root collar diameter was reduced by transplanting and by undercutting for all species except Japanese larch and the broadleaved species, which were not affected by these treatments. The lowest plant densities consistently produced plants with root collar diameters very significantly larger than the higher densities. Dates of undercutting again produced variable results, and as with the other parameters, significant interactions were very few.

(g). "Sturdiness"

Sturdiness may be expressed as the ratio of root collar diameter to height, and the change in this ratio caused by undercutting or transplanting is shown in Fig. 15b. It can be seen from Fig. 15b that, on average, transplants are the 'sturdiest' plants and uncut seedlings the 'spindliest' plants, although differences are very slight.

(h). General

Perhaps the most significant result of all these experiments lies not in the differences revealed between uncut seedlings, undercut seedlings and transplants, but in the difference within all these categories between plants raised in different nurseries over a few seasons. Although Fig. 14 and 15 contain results of several species, not all of the variation in the vertical scale is due to this, e.g. the root weight of Scots pine transplants varied from 0.6 to almost 6 gms. per plant—a tenfold difference. The fact that plants of the same age and type can vary so much indicates that present nursery practice is far from standardised, and is not geared to the production of any minimum standard of plant suitable for planting.

Results—Forest Stage

(a). Survival

In Scotland, assessment data for first-year survival from three-quarters of the experiments were not statistically analysed as the survival rate exceeded 96 per cent in all plots. Even in the experiments which were analysed, significant differences were few and not consistent between experiments. In one experiment on oak (Saltoun 4 P.56), however, the most severe treatment, which was undercutting at 4 in. in August of the second year, reduced the survival rate from 98 per cent (average of other treatments) to 71 per cent. In England, Corsican pine transplants had the best survival rate and 2+0 the worst, the difference usually being very significant (see Table 28). In the two experiments where dates of undercutting of Corsican pine were included, the June treatments produced stock with the best survival rates. The first year survival of other species in England was not usually affected by nursery treatments.

Table 28

PERCENTAGE SURVIVAL OF CORSICAN PINE AT THE END OF THE FIRST GROWING SEASON IN THE FOREST

Treatment	Experiment				
	Bramshill 1 P. 53*	Bramshill 2 P. 54*	Wareham 107A P.55	Wareham 107B P.55	Wareham 112 P.56
2 + 0	66	89	20	16	53
1 u 1	80	99	40	60	58
1 + 1	99	98	89	97	75
Statistical Significance	xx	ns	xx	xx	xx

Notes:—1. Statistical significance. The statistical significance shown refers to the most significant difference between any two of the three treatments.

ns = not significant (P = 0.05)

x = significant (P = 0.05)

xx = very significant (P = 0.01)

2.* In 1954, May and June were much cooler and wetter at Bramshill than in 1953, and this may explain the better survival in 1954

(b). Height

Significant differences in height growth between treatments in the forest were usually related to differences in height in the nursery, but the relative differences and their significances always decreased as the plants grew older, so that in almost all cases height differences after six years in the forest were negligible. (see Table 29).

Discussion

In general, nursery treatments had little effect on plant survival either in the nursery or in the forest on any of the species tested *except* Corsican pine.(See Table 28). This pine is notorious for its planting losses. In fact, only with this species is there any evidence that transplants are more likely to survive than seedlings or undercut plants. Undisturbed seedlings of this species suffered heavy losses on planting and it must be concluded that transplanting is to be recommended for Corsican pine even though this operation in itself reduces plant numbers.

Since in fact (with the exception of Corsican pine) little difference in survival rate and subsequent growth in the forest has been attributable to these very contrasting types of stock, the various measures of plant quality applied in the experiments (top weight, root weight, sturdiness etc.,) have not helped very much to define the 'good' plant. It has been shown that 'balance' and 'sturdiness' are enhanced by root disturbance, and to a greater extent by transplanting than by undercutting, but under the conditions of these experiments it has not been shown how much this matters. Greater differences are in any case attributable to the nursery.

No doubt the results might differ in very large-scale planting with a greater general hazard. Nevertheless, apart from the usual close supervision of Research

Table 29

MEAN HEIGHT OF SOME OF THE UNDERCUTTING FOREST EXTENSION EXPERIMENTS

Species, Nursery Experiment, and Forest Experiment	Treatment	Nursery Height (at 2 years)	Height 3 years after planting	Height 6 years after planting
Scots pine . .	2+0	0.6	1.8	4.9
Fleet 7/54 . .	1 u 1	0.6	1.8	4.9
Devilla 7 P.56 .	1+1	0.3	1.6	4.3
	Statistical Significance	xx	x	ns
	Precision (C%)	11	10	9
Scots pine . .	2+0	0.8	1.2	2.9
Newton 7/55 . .	1 u 1	0.7	1.2	3.0
Speymouth 5 P.57 .	1+1	0.4	1.0	2.7
	Statistical Significance	xx	x	ns
	Precision (C%)	8	10	9
Corsican pine. .	2+0	0.4	1.2	4.3
Bramshill 12/54 .	1 u 1	0.2	1.2	4.4
Wareham 112 P.56 .	1+1	0.2	1.3	4.5
	Statistical Significance	x	na	ns
	Precision (C%)	18		17
Japanese Larch .	2+0	0.6	1.5	4.0
Wauchope 1/55 .	1 u 1	0.5	1.5	4.0
Drumtochty 20 P.57	1+1	0.4	1.6	4.2
	Statistical Significance	x	ns	ns
	Precision (C%)	11	13	12
Sessile oak . .	2+0	0.6	2.5	4.3
Bush 3/54 . .	1 u 1	0.5	2.4	4.3
Saltoun 4 P.56 .	1+1	0.5	2.6	4.4
	Statistical Significance	xx	ns	ns
	Precision (C%)	11	11	10

Notes:—1. Statistical significance.

na = not statistically analysed because differences unimportant

ns = not significant (P=0.05).

x = significant (P=0.05).

xx = very significant (P=0.01).

The statistical significance shown refers to the most significant difference between any two of the three treatments.

2. C%=coefficient of variation.

planting, conditions in these experiments were not specially favourable. Sites ranged from blanket peats in the north of Scotland to southern English heaths. It should however be mentioned that all the Scottish forest sites and most of the English were freshly-ploughed ground. Undoubtedly cultivation has improved since the early experiments reported by Zehetmayr (1960) in which seedlings compared poorly with transplants. In these experiments also the density of the seedbed has been controlled and the type of seedling produced in overstocked beds (left to 'grow on') has not been represented. Better looking seedlings, undisturbed or undercut, were produced at the lower densities, but here again it appears that under the conditions of the experiments, we were not working outside the critical range.

While variation in dates of undercutting gave large apparent differences in the resulting plants (though not in their performances), there was little consistency in the pattern. In certain nurseries undercutting in the spring of the second year gave larger root systems, in others undercutting in the summer appeared more successful. It was found that undercutting was best carried out with the soil moist but firm, confirming other workers e.g. Eide and Grimm (1958). There is some suggestion (Faulkner 1958) that undercutting is best done in periods of maximum root activity either in the spring or (in the north) in July.

Plainly it cannot be decided whether a seedling, undercut or not is 'as good as' a transplant till large numbers of these types have been subjected to the hazards of large-scale planting, which so far has only been undertaken in East Scotland, where the results generally confirmed those of the series of experiments reported here (Petrie 1958). There are also broad questions of nursery practice and economy to be considered. But these experiments certainly offer little support for the widely held view that transplanting is essential; if a *prima facie* case for the use of seedlings (undercut or not) can be made out on grounds of nursery economy, there is certainly encouragement for further research on their production and use, and on the new nursery problems that will arise.

Although the results do not show this (except in the case of Corsican pine) it is not an unreasonable assumption that undercut stock would probably show considerable advantages over undisturbed seedlings in large-scale use. Much attention has been paid to the techniques of undercutting and to the design of instruments for the operation (Faulkner, 1953-55; Shaw, 1956; Stoeckler and Jones, 1957; Eide and Grimm 1958; Clifford, 1956; Wycoff, 1959; Baker, 1961).

There is no reason to suppose that the practice is inapplicable to British conditions, though it is probable that more careful selection of nursery sites, especially with regard to soil physical conditions, would be required.

Summary

Some forty nursery experiments on a number of conifer and broad-leaved tree species, testing various depths and seasons of undercutting, and comparing undercut plants with transplants and undisturbed seedlings of the same age, failed to show any important differences in survival rates or growth in the forest attributable to the type of plant; except in one species, Corsican pine, where transplants were superior to seedlings and undercut stock intermediate in survival value.

Treatment produced marked differences in what are usually considered to be important characteristics, transplants on average being 'better balanced' and sturdier than seedlings, and undercut stock intermediate in these respects. However, the differences in size of stock attributable to the treatment received in the nurseries in which they were grown were very much larger than those brought about by any of the experimental treatments.

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COMPILATION OF THE WESTONBIRT ARBORETUM CATALOGUE BY ELECTRONIC COMPUTER

By J. N. R. JEFFERS

Introduction

The compilation of a catalogue for Westonbirt Arboretum by use of an electronic digital computer might, at first sight, seem an odd procedure. There were, however, a number of basic considerations which prompted the decision to compile and maintain the catalogue on the computer. First, the catalogue of the arboretum was some 30 years out of date and it was necessary to derive the basic information from planting records and from careful surveys in the field of the trees and shrubs which were present, to identify those plants which were not already labelled, and to check the identification of those which had been labelled. The necessary information was contained in the field survey books, each covering one or more sections of the arboretum, and comprised:—

(i) The tree number, within the section.

(ii) The genus and species, if known.

(iii) General notes about origin and date of planting.

Second, for administrative purposes, three different types of record were required;

(i) A list of the plants in order of their numbers within sections.

(ii) A list of the trees in alphabetical order of genus and species within each section.

(iii) A list of the plants in alphabetical order of genus and species over all sections.

It was also desirable to be able to produce special lists of plants from time to time, e.g. a list of all the *Acer* species in the arboretum, a list of all the unidentified *Rhododendrons*, etc.

Third, some sections of the arboretum still remained to be surveyed, and, for these new sections, lists would need to be prepared and the overall alphabetic list re-compiled. New plantings and fellings would also be likely in every section, and amended versions of the lists would be required at least yearly.

Fourth, the nomenclature used in the labelling and recording of the trees was far from consistent, and it was likely that the first version of the catalogue would require considerable amendment before it could be regarded as reasonably correct.

For all of these reasons, it was necessary, therefore, to find some way of compiling the catalogue that was sufficiently flexible to allow for a considerable amount of amendment and extension. Conventional clerical systems were examined, but none seemed to have the desirable properties and, at the same time, to be reasonably economical of time and money. At this stage, it was suggested that the catalogue might be compiled and maintained on an electronic digital computer.

Although the Forestry Commission Research Branch had been making extensive use of electronic digital computers over a wide range of applications to problens of forestry research and management, no previous attempt had been made to programme a computer to undertake a task of this sort. One of the subsidiary objects of the exercise was, therefore, to assess the suitability of these machines for such a task. The Ferranti Sirius computer, already in use on other forestry problems, was used for compilation of the catalogue.

Data Preparation

Before the Sirius computer could begin on the task of compiling the catalogue, it was first necessary to convert the basic field records into a form capable of being read by the computer. The form chosen was that of punched paper tape, partly because of the convenience of this form for transport and storage, and partly because the particular programming system that it was planned to use was itself based on paper tape input and output. The field survey books were first carefully edited to remove any glaring inconsistencies, superfluous comments, etc. The edited information was then transferred to punched paper tape by a skilled machine operator. This operator took very great care to transfer the information correctly, and was experienced, to a certain extent, in the spelling and interpretation of tree names. Nevertheless a copy of the information on her first tape was compared with the field books and any mistake noted. An edited version of the data tape was then prepared. The whole operation, excluding the initial editing of the field survey books, cost less than £50.

Compilation of Catalogue

Once the data tapes had been prepared, the compilation of the catalogue could begin, and this was done in three stages.

(a) The data tapes were first read into the computer, a section at a time. The computer was programmed to sort the entries into their correct numerical order, to produce a new tape, giving the data in tree order within sections. This tape was then read through a standard teleprinter to produce the lists provided in the draft catalogue. The new tape replaced the original unsorted tape, which was then destroyed. Part of the list for one Section is given in Table 30.

Table 30

SECTION LIST IN ORDER OF TREE NUMBER

WESTONBIRT ARBORETUM CATALOGUE. SECTION 6

(Tree No.)	*(Genus)*	*(Species)*	*(Remarks)*
1	SEQUOIADENDRON	GIGANTEUM	GROUP
2	FOTHERGILLA	MAJOR	
3	NOTHOFAGUS	PROCERA	P 1946
4	PRUNUS	AVIUM FLORE PLENO	
5	NYSSA	SYLVATICA	
6	ILEX	AQUIFOLIUM CV	
7	TILIA	OLIVERI	
8	ACER	CARPINIFOLIUM	P 1946
9	EUONYMUS	SP	GROUP
10	DEUTZIA	CARMINEA	
11	ACER	SP	FORREST 32

(b) The new data tapes were next read into the computer under the control of a second programme, designed to sort the entries into alphabetical order by genus and species. At first sight, this might seem an impossible task, but it is, in fact, relatively simple to transfer alphabetical information into numbers, e.g. by giving each letter its number in the alphabet, and then to sort the compound numbers formed from these separate letters. The more difficult problem is that of arranging the sorting process so that each entry is moved in the store of the machine only a limited number of times. By virtue of the special properties of the method of programming used, however, it was found possible to sort 200 entries in rather less than 4 minutes. The resulting list in alphabetical order was then punched on to a new tape, and this tape read through a teleprinter to produce the lists provided in the draft catalogue. Both the alphabetic list and the original list in tree number order were preserved

Part of the alphabetic list for one section is given in Table 31.

Table 31

SECTION LIST IN ALPHABETIC ORDER

(Ref. No.)	*(Genus)*	*(Species)*	*(Section No.)*	*(Tree No.)*
1	ABIES	GRANDIS	6	19
2	ACER	CARPINIFOLIUM	6	8
3	ACER	DAVIDI	6	83
4	ACER	GRISEUM	6	78
5	ACER	PALMATUM DISSECTUM	6	82
6	ACER	PALMATUM RIBESIFOLIUM	6	16
7	ACER	PLATANOIDES	6	49
8	ACER	SP	6	11
9	ACER	SP	6	30
10	ARONIA	ARBUTIFOLIA	6	23
11	ARONIA	ARBUTIFOLIA ERECTA	6	68
12	ARONIA	MELANOCARPA	6	24
13	BERBERIS	SP	6	39
14	BERBERIS	SP	6	64
15	BERBERIS	VEITCHII	6	43
16	BERBERIS	VIRESCENS	6	95
17	CARPINUS	BETULUS	6	65
18	CEDRUS	ATLANTICA	6	40
19	CEDRUS	ATLANTICA	6	66
20	CEDRUS	ATLANTICA GLAUCA	6	21

(c) In order to produce an alphabetic list over all Sections a much simpler procedure was possible. The lists in alphabetic order for two Sections were read into the computer at the same time, in such a way that the entries were merged into a single list in the correct order. By repeating this merging operation a number of times, a complete list of the trees in the Arboretum, in strict alphabetic order by genus and species, was produced.

Part of the merged alphabetic list is given in Table 32.

The total cost of this compiling process was about £100.

Future Procedure

The catalogue will be maintained by the following procedure:

(a) Each year, the list of changes in the catalogue—either of trees that have been felled, or of trees that have been planted, or changes in nomenclature or identification, will be transferred to punched paper tape. Then, by means of a special updating programme, the new data will be inserted, or the old data amended, by the computer. A new list will therefore be produced automatically each year.

(b) As further surveys are done, the data arising from them will be transferred to punched paper tape, and the same procedure followed as was used in the compilation of the original catalogue. The alphabetic list for the new

Table 32

COMPLETE ALPHABETIC LIST

(Ref. No.)	(Genus)	(Species)	(Section No.)	(Tree No.)
1			7	6
2	ABELIA	GRAEBNERIANA	10	62
3	ABIES	ALBA	19	189
4	ABIES	ALBA	8	26
5	ABIES	ALBA	8	30
6	ABIES	ALBA	10	86
7	ABIES	ALBA	11	19
8	ABIES	ALBA	11	44
9	ABIES	ALBA	12	199
10	ABIES	ALBA	12	213
11	ABIES	ALBA	13	12
12	ABIES	ALBA	13	232
13	ABIES	ALBA	14	38
14	ABIES	ALBA	15	104
15	ABIES	ALBA	19	160
16	ABIES	ALBA	19	201
17	ABIES	ALBA	20	37
18	ABIES	AMABILIS	12	186
19	ABIES	AMABILIS	16	11
20	ABIES	BALSAMEA	13	155
21	ABIES	CEPHALONICA	7	181
22	ABIES	CEPHALONICA	8	39
23	ABIES	CEPHALONICA	10	37
24	ABIES	CEPHALONICA	13	208
25	ABIES	CEPHALONICA	14	78
26	ABIES	CILICICA	12	191
27	ABIES	CONCOLOR	7	161
28	ABIES	CONCOLOR	12	207
29	ABIES	CONCOLOR	15	158

Section will be merged with the complete alphabetic list to bring it up-to-date.

(c) As and when they are required, special lists will be produced from whichever of the data tapes they can most easily be derived. Such lists might include a list of all the plants which have not been identified, a list of all the *Rhododendron species*, etc.

(d) Any wholesale modifications of nomenclature would be dealt with by a special run of the data, probably at the same time as the updating and amending of the Section lists. In this way it would be possible to keep the catalogue up-to-date to an extent only possible by the use of extensive and permanent clerical staff.

General Evaluation of Method

This method of compiling a catalogue, tried as an experiment for Westonbirt, proved to be a success. It was possible to compile the catalogue at only a fraction of the time and cost necessary to produce an equivalent catalogue by conventional clerical methods. Many of the difficulties that were expected in the process never materialized, and it was also found possible to improve radically some parts of the computer programmes which at first trial seemed unpromising. Perhaps the greatest benefit that has been derived from this unusual application of a computer, however, is the flexibility in the way in which the information contained in the catalogue is held, and the ways in which it can be kept up-to-date, or presented, as the demand arises.

A SYSTEM OF CO-ORDINATE CODE NUMBERS DERIVED FROM THE NATIONAL GRID FOR USE IN FORESTRY INVESTIGATIONS

By H. DOWDEN and JUDITH J. ROWE

In the past, forests have been coded in various ways for reference in filing and identification systems, but these numbers have had a limited range of uses. Any numerical system can be used for sorting, but most systems cannot be directly used for relating numbered locations to their positions on the ground or on maps.

It is highly desirable to have a system which can be used for *location* as well as identification and sorting, and the solution proposed here is the use of Ordnance Survey 'National Grid' co-ordinates for the code, with simple conventions which make the code suitable for use with automatic data processing equipment. The National Grid is described in the Ordnance Survey publication entitled *The Projection for Ordnance Survey Maps and Plans and the National Reference System.* H.M.S.O. 1951. Price 2s. 0d.

Description of the System

The National Grid has its origin at a point to the South and West of the Isles of Scilly. This origin is accurately described by a twelve figure reference, and grid references are given in terms of the distance in metres to East and North of this point. Thus when a full 12-figure reference is given any point in the British Isles can be located within a square whose side is one metre in length. One-inch Ordnance Survey map sheets (which are individually numbered) normally have notes explaining how to find grid references, but for computations it is inconvenient to use either of the systems which have been described on the maps. These are firstly the system in which the 100 kilometre squares are referred to by pairs of letters (e.g. SH 485708) and secondly the system in which the 100 kilometre square numbers are placed in front of the rest of the reference and separated from it by a stroke (e.g. 23/485708). Since all gridded O.S. maps have the 100 kilometre square numbers on every sheet, the Eastings and Northings for a full co-ordinate reference can always be found.

In the proposed system the number of figures given as co-ordinates are always related to the twelve figure reference for the grid origin, the implication being that omitted figures are noughts at the right-hand end of each part of the co-ordinate reference. Thus only a slight modification is necessary to use the normal National Grid reference for this code. This is to insert the number of the 100 kilometre square before the Easting and Northing parts of the reference respectively. Hence the above example would read 2485 (Easting) 3708 (Northing).

It is understood that the Meteorological Office intends to use full numerical National Grid references for the various recording stations listed in the publication "British Rainfall", for ease of handling on the electronic computer, especially in hydrometric calculations.

Table 33

CATEGORIES OF CO-ORDINATE CODE NUMBERS

Features described	*Number of Figures in Co-ordinate Reference*			*Lengths of Sides of Areas Denoted by Co-ordinates*	
	Total	Eastings	Northings	Eastings	Northings
1. Counties	4	2	2	10 kms. ×	10 kms.
2. Working Plan areas	5	2	3	10 kms. ×	1 km.
3. Working Plan sections, 'Forests', Beats	6	3	3	1 km. × (1000 m. ×	1 km. 1000 m.)
4. Isolated blocks	8	4	4	100 m. ×	100 m.
5. 'Points'	10	5	5	10 m. ×	10 m.

Table 33 shows that each of the five categories of unit normally required in forest research or investigations concerned with management can be identified as such by the total number of figures quoted in the code for the individual units. An unique code number can be given to every unit in every category.

(1.) Counties

This is the largest unit coded within this system, but two-figure references could be used for very large areas.

(2.) Working Plan Areas

Since for practical purposes it is necessary to distinguish between Working Plan areas and counties, although these may be comparable in size, five figure references are used for the former; the convention is to omit the third digit of the *Easting*, from the six figure reference. This reference then defines a rectangle with its long axis running West to East.

(3.) Working Plan Sections, 'Forests', Beats

Working Plan sections are defined in the Forestry Commission Working Plan Code. The term 'forest' is used for areas named (either now or in the past) in the Annual Reports of the Forestry Commission. They may or may not correspond to Working Plan sections. Beats are the recognised divisions of large forests or Working Plan sections.

(4.) Isolated Blocks

This category includes all such items as groups of, or single, compartments, nurseries, research experiments and other objects of similar dimensions.

(5.) Points

This category denotes a reference of great precision, and is reserved for locations which have been adequately surveyed on the ground. Such locations can only be plotted on gridded maps of a scale of not less than six inches to the mile. It might include such items as permanent soil pits, experiments within nurseries, individual trees or plot corners.

Preparation of Co-ordinate Code Numbers

To arrive at the code number assigned to a location the approximate centre of the area on the map is normally used. Part of one Conservancy is given as an example in Table 34 which illustrates the type of list that can be prepared.

Table 34

LIST OF CO-ORDINATE CODE NUMBERS FOR PART OF CONSERVANCY, SOUTH-EAST ENGLAND

Working Plan Area	Code	Working Plan Sections, 'Forests', Beats	Code	Isolated Blocks	Code
Orlestone .	59134	Orlestone	598135	Bannacre and Nothfield	59491435
				Dickers Wood	60241351
				Handen Wood	60531366
				Orlestone main block	59841351
Queen Elizabeth .	47120	Corhampton	458121	Corhampton main block	45831212
		Queen Elizabeth	472119	Great Hanger Wood	47161248
				Hen Wood (E. Westbury)	46611227
				Q.E. Main block (E. Buriton)	47441181
				Upper Bordean	46871267
Rogate	48127	Rogate	482128	Brick-kiln Copse	47831222
				Iron Hill	48461296
				Rogate	48061264

Use of Co-ordinate Code Numbers

(1.) Problems Involving Calculation of Distances from Given Locations

Distances between locations which have been given co-ordinate code numbers may be calculated without mechanical aids. It is not feasible to deal with large quantities of data and calculations by hand, but an electronic computer can be programmed to do so rapidly and accurately.

Such calculations may be used to estimate the amount of material which can be supplied from forests within a given distance of an industrial centre such as a pulp mill or to suggest the most efficient way of supplying forests with plants from any given nursery system.

(2.) Automatic Data Plotting

Using automatic data plotting machines, co-ordinate code numbers can be translated into symbols in their correct positions on a map.

For example, in animal distribution maps the occurrence of damage by an animal may be plotted, in relation to population changes at the locations in which it has been observed.

Similarly, distribution of forests having stated classes of estimated timber volume production at any given time can be shown in relation to industrial centres.

(3.) Simple Location

It has already been indicated that the fundamental use for co-ordinate numbers is to relate any named location to its position on the ground or on a map.

Summary

A system of co-ordinate code numbers based on the Ordnance Survey National Grid is outlined. Unlike other numerical codes in present use, this permits the direct use of code numbers in sorting, mapping and locating places, both by hand and by automatic data processing equipment.

STUDIES OF SOIL MICROARTHROPOD POPULATIONS IN SCOTTISH FORESTS

By DAVID GIFFORD

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Since 1957 work on the microarthropod populations of some coniferous plantation soils has been concerned with the relationship between composition and structure of these populations, and site changes induced by establishment of plantation crops. Recent development of the study on rather different lines is directed toward elucidation of the contribution of various biological agencies to the decomposition of conifer litter, thus it seems appropriate to summarise the results of the early work.

The principal worksite was at the Forest of Ae, Dumfriesshire, and consisted of upland mixed grassland, 900 feet above sea level, at the sampling sites, the ridges of which are dominated by Blue moorgrass *Molinia caerulea* (L.) Moench, on stony drift of Silurian greywacke, carrying 20–30 cms. of recently accumulated raw humus. Here a comparison was made between a *Molinietum* in Compartment 660 and a small area in Compartment 12, planted with Sitka spruce in 1928. To provide subsidiary information on the nature of mite populations in local woodland, and in long-established conifer stands, sampling programmes were also undertaken in mixed oak-alder-hazel scrub in Compartment 208 at the Forest of Ae, on a rich damp mull; at Tomb Wood, Rachan, Peeblesshire, a 185 year old Scots pine plantation on fluvioglacial gravel, with a deep iron podsol; and at the Black Wood of Rannoch, Perthshire, a much disturbed natural Scots pine forest of open structure, in which sampling was confined to the denser forest on mounds of glacial debris, with deep raw humus soils and extensive podsolisation.

In the upper organic soils of these five sites the bulk of the *Mesostigmata* and *Oribatei* were identified, while the *Prostigmata* and *Astigmata* were less thoroughly investigated, largely due to difficulties in identification. The *Collembola* were collected, but await treatment. A quantitative relationship between some of the faunas of *Molinietum* and Sitka spruce litter was obtained, and in some species this was related to the stratification of the upper organic profile. No quantitative aspects of the other studies are comparable to the Ae sampling, and in Table 36 a list disclosing the observed distribution of the species recorded is not treated quantitatively. Such variations in numbers were observed in casual sampling between different sites that comparisons were not possible. This is attributable to the large size of the samples used in this part of the work.

Early interpretation of the effects of plantation establishment (Gifford, 1962, 63) was based on analyses carried out without reference to the nature of the microdistribution of the populations of different species. Later study has shown that it is not advisable to generalise about such distributions. In the Ae and Rannoch faunas much aggregation of the type described elsewhere by the writer (Gifford, in press) was observed. Attempts to relate this to morphological or other characters of the substrate have suffered from imprecision. There is no problem in defining differences between species as regards microdistribution, but closer study is needed to relate this information to the role of different mites in profile development.

Methods

The large-scale collection of microarthropods in soil or litter is limited in practice to methods aimed at separation of the animals from the substrate after selection of samples of the latter, these being processed, if possible, in the laboratory. Methods used in the present study were based on those described by Macfadyen (1953, 1955), while a more recent review (1961) by the same author develops his method and describes the techniques employed in later stages of the present work.

The choice of method lies between some kind of "funnel" technique, based on the creation of gradients in environmental conditions in the sample which are of importance to the animals, such as heat or humidity gradients; and mechanical separation by dispersal of the substrate and removal of the animals on the basis of some difference in physical characteristics, e.g. size or wettability.

The history of funnel techniques originates with Berlese's (1905) water jacketed sieve, which heated the material to be extracted, and induced some of the fauna to abandon their habitat through the sieve plate, the animals being concentrated by the funnel supporting the sieve. Tullgren (1917) placed a lamp above the sample instead of a lateral water jacket, and this method, providing some directional stimulus toward the collecting vessel, has become the basis of all heat-dessication funnel methods. Scandinavian workers, notably Trägårdh (1932) and Hammer (1937) considered that overheating (or possibly any heating) was a primary cause of inefficiency. Ford (1937) developed the first small multiple Tullgren funnels for production of statistically comparable results. Haarlov (1947) developed the ideas of Trägårdh & Forsslund regarding control of temperature and humidity, and he modified his apparatus to avoid condensation on the walls of the funnel, which caused losses. Macfadyen (1953, 1955) went much further in controlling temperature and humidity gradients in the sample, and his most recent apparatus (1961), in which the funnel and the collecting vessel are combined, is highly efficient. Murphy (1955, 1956) described what he termed a split funnel designed to give circulation of air from funnel to lamp chamber, in which he steepened the walls of the funnel sharply to offset losses. Murphy and Macfadyen followed Jacot (1936) and Hammer (1944) in advocating inversion of undisturbed samples for extraction in such apparatus, on the basis that the pore structure would remain undisturbed, and that there would be no tendency for retreat into broken lumps of material due to uniform peripheral dessication in the clods.

Raw (1955) provided a review of the development of modern flotation techniques based on Morris' (1922) apparatus of sieves. Ladell's (1936) use of magnesium sulphate to enhance the difference in specific gravity between animals and substrate, as well as Salt & Hollick's (1944) employment of a paraffin-water mixture to separate plant and animal material floating on the surface, were used by Raw, who improved the Salt-Hollick technique by using benzene, which could be frozen with the arthropods in it, and removed as a disc from the water.

Variation between horizons of the upper organic soil as regards porosity, water content, shrinkage on drying, dispersibility in water, etc., makes it difficult to apply any one method of extraction to comparisons of the fauna in samples from separate horizons without bias in favour of one or other sample, particularly since none of the systems available is capable of producing enumerations relatable to absolute numbers, thus precluding the application of idealised techniques for optimal extraction of each sample, or of each animal species.

In the present study the method adopted is fairly efficient for the extraction of microarthropods other than the Trombidiform mites, but, like all known extraction methods, is suspect with regard to the juvenile stages, which often appear in smaller numbers than the adults. The extractor used for the whole of the early work was based on some control of temperature above the sample, with cooling and water conservation below. Due to the very high shrinkage experienced in the upper soils of *Molinietum* during drying it was found in early extractions that heat was rapidly applied to the sides and under surface of the sample, resulting in drying on the whole outer surface, with trapping of the fauna in a warm, damp central core. This was offset by sleeving the sample ring in an aluminium tube and suspending it wholly in the cool chamber, thus limiting the application of heat to the upper surface of the sample. No attempt was made to determine the efficiency of this apparatus, or of subsequent extractors based on Macfadyen's high gradient funnel, but the numbers obtained indicate at least a moderately good performance.

Collection of the samples was effected in aluminium rings 6.5 cms. in diameter, 3.8 cms. high, these being inserted into the soil with a brass corer provided with a steel cutting edge. Early samples were taken with a solid tube, but the use of smaller samples 2.5 cms. × 1 cm. in later work was achieved with a split brass tube, allowing easy removal of the sample for insertion in the extractor.

Quantitative assessment of the fauna of twig litter, and of the tangle of dead, but standing, *Molinia* stem and leaf was not attempted, but numerous collections were made in these substrates, using a large Tullgren funnel with a 10 inch sieve, in which provision was made to avoid the effects observed by Haarlov (1947), by ventilation of the funnel.

Results

The first experiment was designed to compare the fauna of the upper 3.8 cms. of the organic soil profile under Molinietum in Compartment 660 at Ae with that of the same depth in Sitka spruce in Compartment 12, P.1928. On twelve dates, approximately evenly spaced between May 1957 and May 1958, five sample units, 33 $cm^2 \times 3.8$ cm deep, were collected in the sampling areas of each Compartment, as nearly at noon as possible, the actual siting of sampling being achieved by throwing a scalpel. The results of this sampling are given in Table 35. The precision of identification was not good at this stage of the study, and a number of genera are not treated by species, while some material remained unidentified.

While it was clear (Gifford, 1962) that this programme established marked differences between the two faunas, at least numerically, it was observed that the vertical distribution of many species complicated the comparison. Therefore a second experiment, between September 1959 and August 1960, was designed to study the variation in vertical distribution between species, and the effect of site on this distribution. Again, twelve collections were made, approximately monthly, on each date a pair of sample units being taken from each of the two sampling areas, each unit now subdivided into three vertically arranged cores, 33 $cm^2 \times 3.8$ cm deep. To avoid examination of the whole fauna, nine common species were selected and enumerated in these samples. The results of these enumerations were unfortunately of doubtful value, due to the method of vertical division in the sample, which was too coarse to provide a good measurement of vertical distribution in the *Molinietum*. The results as they were collected for *Veigaia* spp. have been discussed in some detail elsewhere (Gifford, in press), together with an analysis of the distribution of these mites in the horizontal and vertical planes, and of deficiencies in the sampling method. It has been found that all species tested show marked aggregation, not only horizontally, but in depth also, and it is clear that such aggregation will not be discernible in cases where sample dimensions exceed those of the aggregations, even in a single plane.

Subsidiary sampling in the areas already mentioned, to provide comparative information with which to compare the spruce-*Molinia* faunas, was carried out with the ten inch funnel. The results of this sampling, together with a compilation of all the results of collecting in the early stages, are presented in Table 36. Here dominance is indicated by double starring.

To group the species listed to erect *Synusiae* in the manner of Strenzke (1952) would, it is considered, be unrewarding. The complexity of variation in substrate in all dimensions appears to make it likely that any specialisation regarding habitat among coniferous forest species is likely to lead to fragmentation of any such community. There seems much more likelihood that particular species are involved in fairly well-defined stages in the process of destruction of the litter, and that a number of rather weakly-related food chains are present in each locality. This is borne out by the extensive speciation in many of the genera, and the appearance of many closely related species in close proximity. To investigate this aspect of the mites' activity requires that attention be paid to their feeding habits, in particular their relationship with the microflora and other microorganisms. The reorientation of this study has been governed by these considerations.

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Table 35

SAMPLE POPULATIONS OF SELECTED ACARINA IN C. 12, SITKA SPRUCE, AND C. 660, MOLINIETUM AT AE FOREST; EACH FIGURE DERIVED FROM THE MEAN OF FIVE UNITS

	30.v.57 Spruce C. 12	30.v.57 Molinia C. 660	20.vi.57 Spruce C. 12	20.vi.57 Molinia C. 660	4.vii.57 Spruce C. 12	4.vii.57 Molinia C. 660	5.ix.57 Spruce C. 12	5.ix.57 Molinia C. 660	26.ix.57 Spruce C. 12	26.ix.57 Molinia C. 660	31.x.57 Spruce C. 12	31.x.57 Molinia C. 660
Parasitidae	12·6	8·2	7·4	7·4	8·8	3·0	6·4	7·0	10·2	13·6	10·8	10·6
Macrholaspis opacus	2·4	0·2	1·2	0·4	1·1	0·2	1·1	0·6	1·8	1·2	1·6	1·8
Geholaspis longispinosus	1·8	—	—	—	0·8	0·2	0·6	0·8	1·4	1·4	2·2	0·2
Veigaia nemorensis	13·8	6·6	4·6	4·2	9·4	2·6	8·8	5·0	12·2	9·2	17·0	10·4
V. transisalae	8·8	5·6	3·8	5·8	5·4	2·4	5·2	6·2	8·2	6·8	10·0	8·2
V. cervus	1·4	3·2	1·8	3·0	2·2	2·6	1·4	4·4	3·8	6·2	5·2	7·6
V. kochi	0·8	0·2	—	0·2	1·4	—	0·4	—	1·2	0·8	2·0	0·2
Eviphis ostrinus	3·0	2·4	1·2	1·8	2·6	1·6	1·4	2·2	3·6	3·4	5·8	2·2
Olodiscus minimus	14·2	4·8	8·2	2·6	11·0	2·2	9·6	5·2	12·8	7·4	15·6	4·8
Juvenile and indet. Mesostigmata	8·6	5·0	2·4	4·0	4·6	1·8	6·3	11·4	7·6	11·4	8·8	8·2
Total Mesostigmata	67·4	36·2	30·6	29·4	47·3	16·6	41·2	42·8	62·8	61·4	79·0	54·2
Hypochthonius rufulus	1·8	7·0	0·8	3·8	0·4	6·2	3·8	8·2	4·8	4·4	4·2	6·2
Eobrachychthonius sellnicki	13·4	9·2	8·4	9·8	7·2	7·8	10·2	6·6	8·2	14·2	15·8	9·8
Brachychthonius sp.	10·6	3·6	5·8	6·2	4·2	4·0	8·8	2·0	9·8	11·2	10·2	6·6
Nanhermannia nanus	5·6	16·2	9·8	15·4	11·2	10·8	7·4	14·2	12·2	16·4	13·8	12·4
Malaconothrus monodactylus	—	8·0	—	8·2	—	4·6	2·2	10·6	4·8	14·2	6·2	15·2
Trimalaconothrus glaber	—	6·2	—	3·8	—	7·8	—	8·6	1·8	6·8	1·8	8·4
Camisia spinifer	2·2	0·4	1·2	—	3·6	0·6	3·8	0·2	1·6	—	3·8	—
Camisia segnis	0·6	—	0·4	1·2	0·2	—	0·8	—	0·2	—	1·2	2·2
Platynothrus peltifer	30·8	24·2	22·2	33·6	26·4	31·2	13·6	33·8	20·2	42·8	29·8	36·4
Nothrus sylvestris	3·8	1·6	4·8	—	2·8	—	3·0	11·6	1·4	—	3·4	—
Pelops spp.	1·6	14·2	0·4	9·4	1·0	12·2	0·8	7·4	2·2	91·6	1·8	10·2
Achipteria coleoptrata	—	—	—	5·4	—	—	—	1·2	—	—	—	2·4
Ceratozetes gracilis	1·4	8·8	—	2·2	0·4	10·2	0·6	—	—	—	0·4	—
Chamobates pusillus	—	—	—	0·8	—	—	—	—	—	—	—	—
C. schutzi-incisus spp.	17·8	31·2	9·4	18·4	12·6	20·8	7·0	24·8	7·8	30·2	10·8	28·4
Liebstadia similis	7·8	10·6	5·8	6·8	6·2	7·4	4·4	13·2	5·6	11·8	7·8	8·8
Carabodes minusculus	—	4·2	0·8	0·2	—	5·4	—	3·0	—	1·4	—	—
Tectocepheus velatus	3·4	—	—	—	2·0	2·2	—	10·4	2·8	4·8	1·8	6·6
Adoristes sp.	5·8	11·8	8·4	7·8	9·8	9·0	8·2	23·2	3·2	17·6	8·2	19·6
Suctobelba spp.	8·4	8·6	6·8	10·4	5·8	6·8	4·4	7·8	6·4	13·4	10·2	12·2

Table 35—*continued*

	30.v.57		20.vi.57		4.vii.57		5.ix.57		26.ix.57		31.x.57	
	Spruce C. 12	Molinia C. 660	Spruce C. 12	Molinia C. 660	Spruce C. 12	Molinia C. 660	Spruce C. 12	Molinia C. 660	Spruce C. 12	Molinia C. 660	Spruce C. 12	Molinia C. 660
Oppia spp.	37·2	49·8	34·6	42·2	38·2	45·8	22·8	69·0	39·2	57·8	60·8	63·4
Ceratoppia bipilis	3·8	7·8	1·8	3·6	4·4	5·2	1·2	8·2	3·8	6·8	4·8	5·4
Oribella lanceolata	14·2	2·6	12·6	0·8	10·8	—	9·8	6·2	10·8	3·2	12·6	1·6
Damaeus tenuipes	—	6·4	—	2·2	—	8·0	—	2·8	—	7·0	—	2·2
Porobelba spinosa	0·8	—	—	—	—	—	—	—	—	—	0·8	—
Juvenile and indet. Oribatei	18·2	60·8	29·6	47·4	32·4	25·6	82·2	188·4	107·2	207·6	162·4	195·8
Total Oribatei	189·2	293·2	163·6	239·6	179·6	231·6	195·0	614·4	254·0	481·2	372·6	453·8
Tarsonemini	11·8	36·4	14·4	47·2	8·2	18·8	22·2	30·2	15·4	29·2	79·4	22·4
Prostigmata	17·4	28·2	35·6	19·2	11·8	41·4	19·4	48·2	29·2	32·2	48·2	36·4
Acaridae	24·8	18·0	37·2	8·6	20·6	11·2	96·6	35·8	189·4	30·2	298·6	13·6
Collembola	219·6	272·6	116·4	255·6	121·8	182·0	206·2	210·4	221·4	197·4	409·2	318·4
	27.xi.57		**4.ii.58**		**24.ii.58**		**10.iii.58**		**3.iv.58**		**8.v.58**	
	C. 12	**C. 660**	**C. 12**	**C. 660**	**C. 12**	**C. 660**	**C. 12**	**C. 660**	**C. 12**	**C. 660**	**C. 12**	**C. 660**
Parasitidae	17·2	5·8	3·6	4·8	6·2	6·2	5·8	8·2	7·4	5·0	4·8	6·2
Macrholaspis opacus	1·2	0·8	0·6	0·4	1·2	1·4	—	0·4	0·6	0·4	1·2	0·8
G. longispinosus	1·8	1·6	0·6	—	0·6	0·2	0·4	—	1·0	—	—	0·2
Veigaia nemorensis	15·8	7·2	6·8	4·8	9·2	7·2	5·2	6·2	8·2	5·0	11·4	7·0
V. transisalae	9·6	6·2	4·0	3·2	3·6	6·6	2·8	5·8	4·8	6·8	3·8	4·8
V. cervus	4·0	4·8	1·2	3·6	1·4	4·8	0·8	3·6	3·0	3·2	5·8	8·0
V. kochi	0·8	0·2	0·4	—	1·2	—	0·2	0·2	—	—	1·2	—
Eviphis ostrinus	4·2	1·6	1·8	1·8	1·8	1·4	1·4	2·2	2·2	2·8	3·0	1·6
Olodiscus minimus	20·2	3·2	6·2	2·4	7·2	3·2	3·2	5·4	7·4	3·4	9·6	2·6
Juvenile and indet. Mesostigmata	13·2	7·2	3·2	2·8	9·6	4·4	6·2	3·8	5·2	2·2	6·6	3·4
Total Mesostigmata	88·0	38·6	28·2	23·8	42·0	35·4	26·0	35·8	39·8	28·8	47·4	34·6
Hypochthonius rufulus	2·6	2·4	0·6	1·4	0·4	2·8	2·2	1·6	0·8	4·2	—	6·2
Eobrachychthonius sellnicki	13·8	14·2	6·4	5·6	10·8	8·4	17·6	10·6	13·2	16·2	5·6	12·6
Brachychthonius sp.	12·2	3·8	2·2	6·2	9·0	2·2	5·4	3·4	6·2	1·8	3·4	3·2
Nanhermannia nanus	8·4	20·2	1·4	3·8	3·6	14·8	6·6	22·6	7·0	20·2	12·2	18·6
Malaconothrus monodactylus	10·4	18·2	1·8	4·4	1·2	8·2	—	9·8	—	2·6	—	1·8
Trimalaconothrus glaber	3·6	11·8	—	3·6	0·4	4·6	1·6	—	—	4·8	1·8	8·4
Camisia spinifer	1·6	2·2	—	—	1·6	1·2	2·2	—	0·6	1·4	3·4	2·6
Camisia segnis	0·4	—	0·4	—	1·4	—	0·8	0·4	2·2	—	0·8	—
Platynothrus peltifer	41·2	41·8	10·8	14·2	23·2	36·4	24·2	48·2	18·0	52·6	23·6	54·8
Nothrus sylvestris	6·2	2·6	—	—	1·8	—	4·8	—	7·6	—	1·8	—
Pelops spp.	1·2	14·8	—	—	—	8·4	2·2	12·8	0·4	12·2	1·4	21·2
Achipteria coleoptrata	—	3·6	—	2·4	2·6	—	1·2	—	—	1·8	—	3·2
Ceratozetes gracilis	1·4	—	—	—	—	4·4	—	—	2·8	—	—	—
Chamobates pusillus	—	2·6	—	—	1·2	2·4	—	—	1·4	—	—	—
C. schutzi-incisus spp.	8·6	38·6	6·4	12·2	18·4	10·6	9·6	18·2	14·4	26·2	9·6	21·6
Liebstadia similis	6·4	14·2	4·2	16·6	8·2	3·4	10·6	7·6	6·1	2·8	7·2	8·4
Carabodes minusculus	—	2·2	—	—	—	1·8	—	2·6	—	—	0·8	—
Tectocepheus velatus	3·8	2·4	—	1·8	1·0	4·6	—	3·6	2·4	8·2	3·4	9·2
Adoristes sp.	6·2	11·8	—	12·6	8·2	18·2	4·4	11·8	6·1	8·2	2·2	14·8
Suctobelba spp.	14·8	8·6	5·0	9·2	9·4	3·8	9·2	8·4	10·4	4·4	8·6	10·6
Oppia spp.	67·2	82·6	33·2	38·4	50·6	27·4	78·8	46·6	65·2	38·6	36·2	47·4
Ceratoppia bipilis	3·2	12·4	1·2	4·6	6·2	6·6	2·8	4·2	8·0	7·4	14·2	1·4
Oribella lanceolata	8·5	3·6	4·6	0·8	7·8	—	13·2	1·2	9·4	—	17·6	0·8
Damaeus tenuipes	—	7·4	—	3·4	—	3·2	—	2·2	—	10·4	—	3·6
Porobelba spinosa	—	—	—	—	0·2	—	—	—	—	—	—	—
Juvenile and indet. Oribatei	176·6	200·4	48·0	132·8	49·2	152·6	41·4	180·6	61·0	166·4	37·8	60·8
Tarsonemini	42·6	22·4	9·4	20·8	8·2	28·2	26·8	20·6	4·4	23·4	15·2	12·6
Prostigmata	17·2	21·2	11·2	17·4	20·4	21·6	9·2	11·2	12·6	17·6	23·5	30·4
Acaridae	377·2	39·4	140·6	15·6	39·8	14·4	57·0	6·8	32·2	15·8	19·2	24·6
Collembola	444·2	284·2	165·4	98·8	196·8	217·2	228·4	294·0	240·2	310·2	279·6	238·6

Table 36

SPECIES LISTS OF ACARINA FROM FIVE SITES IN SCOTTISH FORESTS

Species	Ae Forest										Tomb Wood			Black Wood		
	Sitka spruce				Molinietum				Oak-Hazel		Scots pine			Scots pine		
	Twigs	L	F	H	Tufts	L	F	H	L	M	L	F	H	L	F	H
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Leptogamasus suecicus Trägårdh														*	*	
Pergamasus spp.	**	**	*	*	**	**	*	*	*	*	*	*	*	*	*	*
Parasitus sp. A	*	*	*		*											
Holoparasitus calcaratus f. siculus Berl.	*	*							*	*		*				
Macrholaspis opacus (C.L.K.)	*	*	*		*	*			*	*	*	*				
Geholaspis mandibularis	*	*	*		*	*			*		*	*				
G. longispinosus (Kramer)	*	*									*					
Macrocheles tardus (C.L.K.)	*	*									*					
M. submotus Falconer	*	*									*					
Rhodacarus roseus Ouds.			*							*		*	*		*	
Veigaia nemorensis (C.L.K.)	**	**	*	*	**	**	*	**	*	*	*	*	*	*	*	
V. transisalae Ouds.	*	*	*	*	*	*	*	*	*	*						
V. cervus (Kramer)	*	*	*	*	*	*	*	*								
V. kochi (Trägårdh)	*	*			*	*			*							
Pachylaelaps longesetis Halb.	*	*														
Epicriopsis horridus (Kramer)	*															
Proctolaelaps robustus Evans														*	*	
Neojordensia levis (Ouds. & Voigts)				*	*											
Arctoseius magnanalis Evans														*		
Lasioseius muricatus (C.L.K.)											*	*				
Microsejus truncicola											*					
Digamasellus circuliformis Leitn.											*	*				
Hypoaspis aculeifer (Canestrini)	*															
Haemogamasus nidi (Michael)					*											
H. hirsutus Berlese					*											
Zerconopsis remiger (Kramer)											*					
Zercon triangularis (C.L.K.)	*	*	*		*	*	*		*	*	*	*		**	**	
Z. sp.=colligans Sellnick nec Berlese	*	*	*						*							
Parazercon radiatus (Berl.)									*	*	*					
Prozercon kochi f. pluripennatus Selln.	*															
Polyaspinus cylindricus Berl.											*					
Trachytes minima Trägårdh	*	*	*	*	*	*	*	*	*	*	*	*		*	*	
Eviphis ostrinus (C.L.K.)	*	*	*	*	*	*	*		*	*	*	*		*	*	
Olodiscus minimus (Kramer)	**	**	*	*	*	**	*		*	*	*	*		*	*	
Cilliba cassidea (Hermann)	*								**	**	*					
Urodiaspis tecta (Kramer)									*	*				*	*	
Imparipes degenerans Berl.					*	*										
Pygmephorus sellnicki Krczal					*	*										
Pygmephorus spinosus Koch					*	*										
Schweibia sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Cocceupodes clavifrons (Can.)	*	*							*							
Cocceupodes sp.									*	*	*					
Eupodes spp.	**	*							*	*	*					
Bdella pinicola Booreman	*	*												*	*	
Cyta latirostris (Hermann)	*	*			*	*			*		*	*		*		
Bimichaelia crassipalpis Halb.	*				*									*	*	
Rhagidia sp.	*	*			*	*			*		*			*		
Ereynetes spp.	*	*			*	*					*					
Lorryia sp.	*	*									*					
Stigmaeus eutrichus	*	*									*			*		
Cryptognathus lagenus (Kramer)														*	*	
Erythraeus phalangoides Degeer					*	*										
Leptus nemorum (Koch)	*				*	*			*	*	*			*		
Podothrombium bicolor (Herm.)									*					*		
Pseudotritia duplicata	*	*							*					*	*	

Table 36—*continued*

Species	Ae Forest										Tomb Wood			Black Wood		
	Sitka spruce				Molinietum				Oak-Hazel		Scots pine			Scots pine		
	Twigs	L	F	H	Tufts	L	F	H	L	M	L	F	H	L	F	H
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P. minima (Berlese)														•		
Phthiracarus piger (Scop.)	•	•			•	•					•	•		•		
Phthiracarus spp indet.	•	•							•		•			•	•	
Hoploderma magna (Nic.)	•	•							•					•	•	
Hypochthonius rufulus (C.L.K.)		•			••	•			•	•	•	•		•		
Eniochthonius minutissima (Berl.) v.d. Hamm.									•	•						
Brachychthonius simplex Forssl.	•	•														
B. perpusillus Berl.	•	•	•		•	•	•		•	•	•	•		•		
Eobrachychthonius sellnicki (Thor)	•	•	•	•	•	•	•		•	•	•			•	•	
Nanhermannia nanus (Nic.)	•	•	•	•	•	•	•	•	•	•	•	•		•	•	
Hermannia gibba (C.L.K.)									•	•	•	•				
Malaconothrus monodactylus (Mich.)		•			•	••										
Trimalaconothrus glaber (Mich.)		•			•	••										
Camisia spinifer (C.L.K.)	•	•	•		•	•			•	•	•	•		•	•	
C. segnis (Hermann)	•	•	•		•	•			•		•	•		•	•	
Platynothrus peltifer (C.L.K.)	•	••	••	•	•	••	••	•	•	•	•	•	•	•	•	•
Nothrus sylvestris (Nic.)	•	•	•		•	•			•	•	•	•		•		
N. palustris C.L.K.						•			•	•				•		
Phenopelops duplex (Berl.)	•	•			•	•			•	•	•			•		
Pelops sp. nr. plicatus (C.L.K.)	•	•	•		••	•			•		•	•		•	•	
Achipteria coleoptrata (L.)	•	•	•		•	•			•	•	•	•		•		
A. nitens (Nic.)											•	•				
Tectoribates tecta (Michael)	•	•							•	•						
Ceratozetes gracilis (Michael)	•	•	•		•	•			•	•	•			•	•	
Chamobates pusillus (Berl.)	•	•			•	•			•							
C. schutzi-incisus spp.	•	••	•	•	•	••	•		•	•	•	•		•	•	
Euzetes globulus (Michael)	•	•	•		•	•			••	•	•			•		
Edwardzetes edwardsi (Nic.)	•								•	•						
Punctoribates semirufus (C.L.K.)	•								•	•						
Melanozetes mollicomus (C.L.K.)	•								•	•						
Licneremaeus licnophorus (Mich.)														•	•	
Caleremaeus monilipes (Mich.)														•	•	
Liebstadia similis (Mich.)	•	•	•	•	•	•	•	•	•	•						
Zygoribatula exilis (Nic.)	•								•	•						
Oribatula tibialis (Nic.)	•	•			•	•			•	•				•		
Gustavia microcephala (Nic.)	•								•	•						
Carabodes minusculus Berl.	•	•	•		•	•	•		•	•	•	•		•	•	
C. labyrinthicus (Mich.)	•	•							•		•			•		
C. marginatus (Mich.)		•												•		
Cepheus cepheiformis (Nic.)	•	•									•	•				
C. latus (C.L.K.)	•	•							•		•			•		
Tectocepheus velatus group	•	•	•	•	•	•	•		•	•	•	•		•	•	
Odontocepheus elongatus (Mich.)											•	•		•	•	
Adoristes ovatus-poppei spp.	•	•	•		•	•			•	•	•	•		•	•	
Xenillus tegeocranus (Herm.)									•	•						
Oppia quadricarinata (Mich.)	•	•														
Oppia nova Ouds.	•	•	•	•	•	•	•	•	•	•	•	•		•	•	
Oppia neerlandica (Ouds.) v.d.H.	•	•			•											
O. ornata Ouds.	•	•	•		•	•	•		•	•	•	•		•	•	
O. subpectinata (Ouds.)	•	•							•	•				•	•	
O. minus (Paoli)					•	•			•	•					•	
Autogneta parva Forsslund									•	•	•	•		•	•	•
Suctobelba similis Forsslund		•	•		•	•			•					•		
S. subcornigera Forsslund					•	•								•		
S. trigona (Michael.)	•	•			•	•										

Table 36—*continued*

Species	Ae forest										Tomb Wood			Black Wood		
	Sitka spruce				Molinietum				Oak-Hazel		Scots pine			Scots pine		
	Pwigs	L	F	H	Tufts	L	F	H	L	M	L	F	H	L	F	H
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
S. sarakensis Forsslund	•	•	•			•										
Eremaeus oblongus (C.L.K.)	•	•			•	•			•	•	•	•	•	•	•	
Ceratoppia bipilis (Hermann)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Phauloppia lucorum (C.L.K.)		•			•	•			•	•						
Oribella lanceolata (Michael)	•	•	•		•	•	•		•	•	•			•		
O. paoli (Ouds.)	•	•							•	•						
Oribata geniculata (L.)					•									•	•	
Damaeus clavipes (Hermann)	•								•	•						
D. onustus (C.L.K.)	•	•							•	•	•			•		
D. tenuipes (Mich.)					•											
Belba corynopus (Hermann)									•	•	•					
Porobelba spinosa Sellnick	•	•	•								•	•				
Metabelba papillipes											•					
Damaeobelba minutissima (Sellnick)		•							•		•	•				

WASTAGE IN INDUSTRIAL GRADES EMPLOYED BY THE FORESTRY COMMISSION

By J. N. R. JEFFERS

Introduction

Preliminary enquiries, based on existing records, have suggested that the structure of the Forestry Commission labour force, by age and length of service, is unsatisfactory, and that the turn-over of labour is sufficiently high to constitute an important problem in forest management. Further information on these questions was however necessary before any definite conclusions could be drawn, and a survey, based on examination of records from a sample of forests, was planned.

This survey had the following specific objects:—

(1.) To determine the structure of the labour force, by age and length of service.

(2.) To estimate the rate of turnover of the labour force.

(3.) To test the hypothesis that rate of turnover is not affected by age or length of service; if the hypothesis is rejected, to estimate the relationship between turnover and age or length of service.

(4.) To test the hypothesis that rate of turnover does not vary from Conservancy to Conservancy; if this hypothesis is rejected, to discriminate between those Conservancies which have high and low rates of labour turnover, and to estimate the probable causes.

Method of Investigation

The survey was based on a series of simple questionnaires from a random sample of forests in each Conservancy. The first questionnaire for each forest asked for the name, age, grade, and length of service of every person employed on 1st October, 1960. Subsequent questionnaires asked for the same information for each new person employed in the sample forest, and for confirmation that persons shown as employed in the first questionnaire were still employed. The data from the questionnaires were coded numerically and punched on to paper tape. Tabulation of frequency tables of various kinds was done by means of electronic digital computers.

Structure by Grades, Age, and Length of Service: October, 1960

At 30th September, 1960, the total number of industrial employees—men, women, and juveniles—was 12,032. The random sample of forests gave a total of 2,186 employees, chosen in such a way as to be representative of the total industrial population. The number of persons in the sample was therefore approximately 18 per cent of the total number of employees.

Table 37 gives the composition of the sample by age, for the whole of England, Scotland, and Wales. The Forest Clerks and part-time workers, who formed only about 3½ per cent of the sample, represent a rather special part of the population. The age distributions of the remaining employees are shown graphically in Figure 16.

The data show two strong peaks in the age classes 35–39 and 50–54 with a marked drop in the numbers of employees in the age classes 40–44 and 45–49. The relatively large number of juveniles also contrasts strongly with the small proportion of workers in the 20–24 and 25–29 age classes. Similar trends are reflected in the age distribution of the established workers. The age distribution of the gangers is smoother, building up slowly to a maximum in the 50–54 age class.

Table 38 gives the composition by length of service of the sample for the whole of England, Scotland, and Wales. Length-of-service distributions of unestablished and established workers, and other grades, are shown graphically in Figure 17.

Table 37

COMPOSITION BY AGE OF THE SAMPLE FOR ENGLAND, SCOTLAND, AND WALES

Age class	Total number of employees in the sample							
	Gangers	Established workers	Un-established workers	Juveniles	Forest Clerks	Other grades	Part-time	Total
15–19 years				276	11		1	288
20–24 ,,	1	2	163	1	10	11		188
25–29 ,,	5	1	131		12	17	1	167
30–34 ,,	12	34	147		7	13		213
35–39 ,,	19	70	128		7	40	2	266
40–44 ,,	20	41	104		7	34	1	207
45–49 ,,	22	45	111		5	29	4	216
50–54 ,,	33	70	116		5	40	2	266
55–59 ,,	27	58	87			20		192
60–64 ,,	15	46	73		1	17	1	153
65–69 ,,	2	1	16			4	1	24
70–74 ,,			3			1	1	5
75–79 ,,			1					1
Total	156	368	1080	277	65	226	14	2186

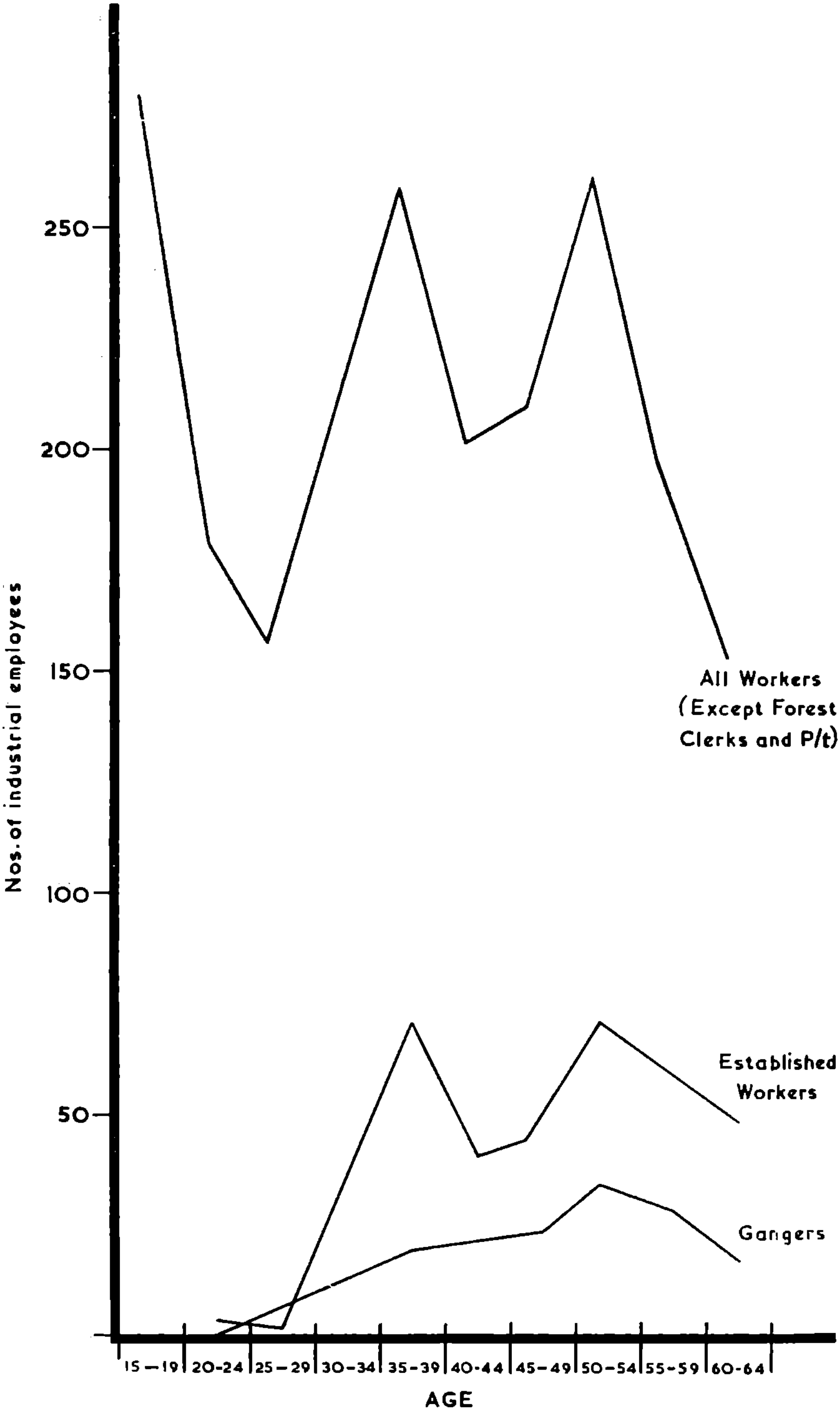

FIGURE 16. Age Distribution of Industrial Workers.
(P/t = Part-time workers)

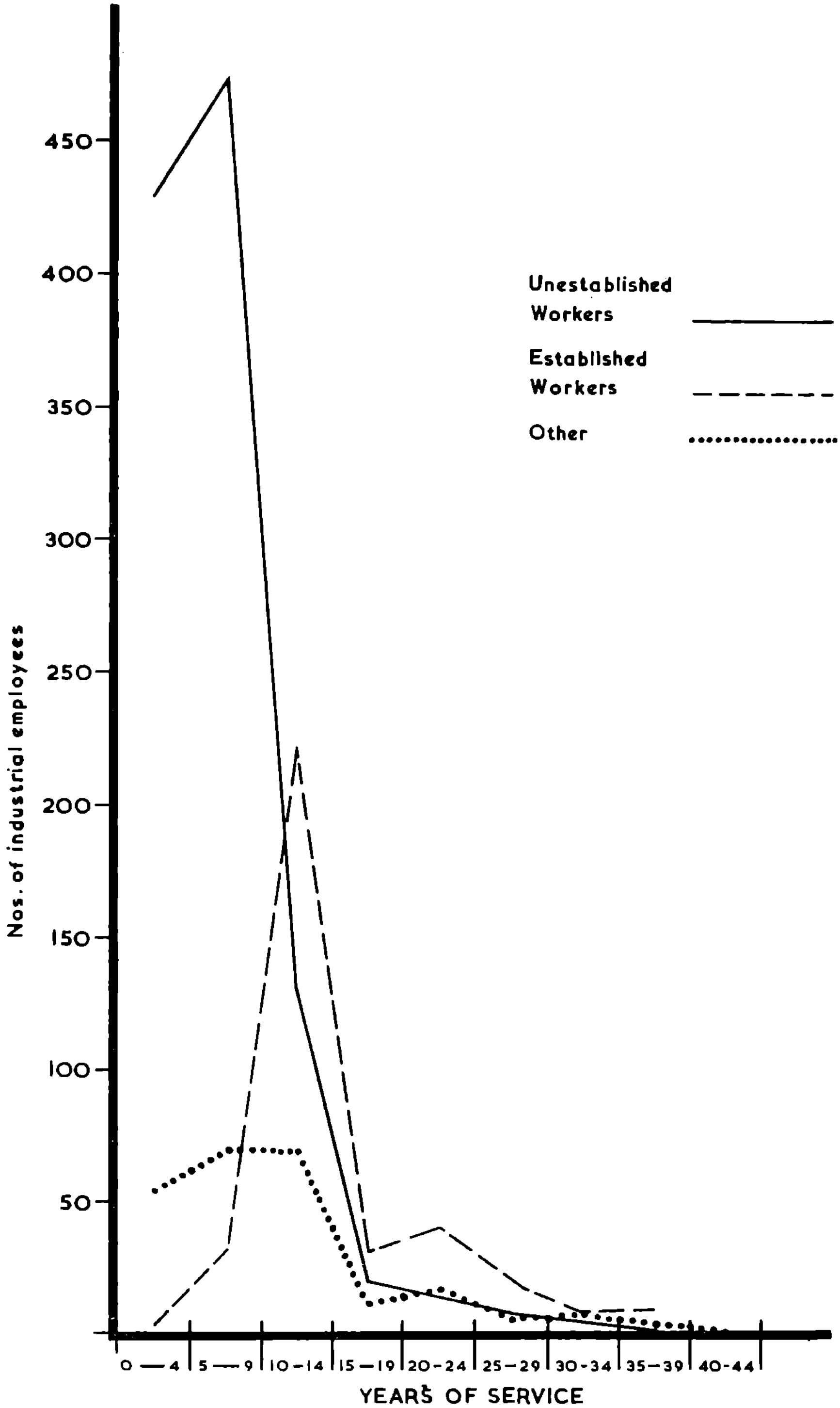

FIGURE 17. Length-of-Service Distributions of Industrial Employees.

Table 38

COMPOSITION BY LENGTH OF SERVICE OF THE SAMPLE FOR ENGLAND, SCOTLAND, AND WALES

Length of service (years)	Gangers	Established workers	Un-established workers	Juveniles	Forest Clerks	Other grades	Part-time	Total
0– 4	9	4	429	277	41	54	7	821
5– 9	36	30	472		16	71	1	626
10–14	60	227	135		7	68	2	499
15–19	7	30	19		1	9	2	68
20–24	23	42	12			15	2	94
25–29	11	19	5			5		40
30–34	8	7	5			1		21
35–39	1	9	2			3		15
40–44	1		1					2
Total	156	368	1080	277	65	226	14	2186

Only eleven per cent of the industrial employees had a length of service of 15 years or more, the modal length of service being in the 5–9 years class for unestablished workers, and in the 10–14 years class for established workers. There were two main groups of gangers, one with lengths of service between 5 and 15 years, and the other with lengths of service of 20 years or more.

The distributions of Table 37 and Table 38 are clearly not independent, even for those grades which are not, by definition, confined to one age or length of service class. Indeed, the way in which the two distributions interact provides a measure of the satisfactoriness of the structure of the labour force, and of the likelihood of difficulties in future deployment of this force. Further studies of this structure are therefore being undertaken.

Subsequent wastage—October 1960 to October 1961

Table 39 gives the numbers of industrial workers leaving Forestry Commission employment, whether for other employment or because of retirement or death, and the numbers of industrial workers transferred to other Forestry Commission forests in the Forest Year following the first questionnaire.

The usual measure of labour turnover is calculated as

$$\frac{\text{Number of workers leaving in period under review}}{\text{Number of workers employed during the same period}} \times 100$$

Applying this formula, the total labour turnover for the Forestry Commission in Forest Year 61 was estimated as 15.8 per cent. Excluding the numbers of workers leaving through retirement or death, the labour wastage was estimated as 14.2 per cent. The rates compare favourably with the findings of the survey on labour turnover of the British Institute of Management in 1949 and 1950, where the annual labour turnover rates varied from 13 per cent to 59 per cent.

Table 39

NUMBERS OF INDUSTRIAL WORKERS LEAVING FORESTRY COMMISSION EMPLOYMENT OR TRANSFERRED TO OTHER FORESTS

Grade	Nos. of workers leaving employment			Nos. Transferred to other forests
	Left for other employment	Retired or died	All reasons	
Ganger	5	2	7	4
Established workers I	8	8	16	12
,, ,, II	0	4	4	2
,, ,, III	1	1	2	0
Unestablished workers I	43	7	50	12
,, ,, II	26	5	31	19
,, ,, III	81	1	72	17
Forest clerks	6	0	6	0
Others	21	7	28	13
Juveniles	113	0	113	17
Part-time	6	1	7	2
Total	310	36	346	98

Most of the turnover in industrial labour occurred among juveniles, where the estimated rate was as high as 40.8 per cent, and among unestablished workers, where the rate was 15.1 per cent. Grading of established and unestablished workers had apparently little effect on the rate of turnover, but, as might be expected, wastage through leaving for other employment was comparatively low among gangers and established workers. There were no strongly marked seasonal trends in wastage in the sample.

The rate of transfer among industrial workers was surprisingly high, 4.5 per cent of all workers in the sample being transferred to other Forestry Commission units within the year. This relatively high rate of transfer was not confined to the "other grades", where it might be expected, but occurred also among, for example, unestablished workers. (The transfer rates for "other grades" and unestablished workers were 5.8 per cent and 4.4 per cent respectively).

Clearly, the rate of labour turnover is not unrelated to the age of the workers and their length of service, and the data suggest that there is a "reservoir" of long-service employees for which the average age is slowly increasing. In addition, there is a second group of shorter-term employees in which the rate of turnover is considerably greater, and from which it will be necessary to recruit the necessary men to replace the experienced workers that are gradually being lost through retirement. Among the floating population of juveniles, two in every five leave for other employment each year. Further study of the relationships between labour turnover and age and length of service in the Forestry Commission is, however, being carried out.

The percentages of wastage of unestablished workers, juveniles, and all other grades for each conservancy are given in Table 40. These percentages are calculated from the numbers of workers leaving for other employment.

Table 40

PERCENTAGE WASTAGE OF INDUSTRIAL WORKERS IN DIFFERENT CONSERVANCIES

Conservancy	Percentage wastage of:—			
	Un-established workers	Juveniles	All other Grades	All Grades
North West England	14.6	33.3	5.3	13.8
North East	11.1	60.0	12.8	17.0
East	8.3	30.0	4.2	7.4
South East	15.0	52.0	5.6	17.6
South West	5.3	23.5	9.8	9.1
New Forest	21.1	18.2	11.8	17.0
Dean Forest	15.8	33.3	2.9	10.2
North Scotland	8.8	21.4	2.7	8.2
East	25.0	31.3	4.6	14.5
South	14.9	29.6	6.7	13.0
West	24.4	20.0	5.0	18.3
North Wales	4.5	23.1	3.2	5.8
South	31.8	82.0	5.1	39.3

There were marked differences between percentages of wastage for different Conservancies. The overall wastage was high for South Wales, and moderately high for West Scotland, South East England, North East England, and the New Forest. Wastage of juveniles was high in North East England, South East England, and, outstandingly so, in South Wales. Wastage of unestablished workers was relatively high in the New Forest, in East and West Scotland, and, again, in South Wales. There was little difference in the rate of wastage among all other grades. South Wales stands out clearly as the Conservancy with a particularly serious problem of labour turnover and wastage.

Changes in Numbers of Forestry Commission Industrial Workers with Time

The total number of industrial employees has been reported regularly in the Annual Report of the Forestry Commissioners, and Table 41 below gives these total numbers for every fifth year in the period 1925–1945, and for every year from 1949 onwards. These data are also shown graphically in Figure 16.

The most striking feature of the changes in numbers of industrial workers is the sharp expansion of the labour force between 1945–1949, when the number of workers was approximately trebled. See Figure 18. Clearly, the existing labour force remains very largely a product of the relatively stable number of workers maintained before this period, and the even greater numbers attracted into the industry at the end of the war. After 1949, the number of industrial workers rose steadily to a maximum of 13,600 in 1954, and has fallen slightly since that date to its present level of about 12,000. The problem of forecasting the numbers of industrial workers required in the future raises some interesting questions, and must clearly be affected by decisions concerning the types and quantities of production, the relative proportions of standing sales, and the degree of mechanisation to be introduced into forest operations.

Table 41

TOTAL NUMBER OF INDUSTRIAL WORKERS (INCLUDING PART-TIME)

Year	Total number of industrial workers at 30th September
1925	2,200
1930	3,100
1935	3,200
1940	4,300
1945	4,600
1949	11,200
1950	12,100
1951	12,200
1952	12,900
1953	13,200
1954	13,600
1955	13,300
1956	13,100
1957	13,000
1958	12,400
1959	12,500
1960	12,000
1961	11,900

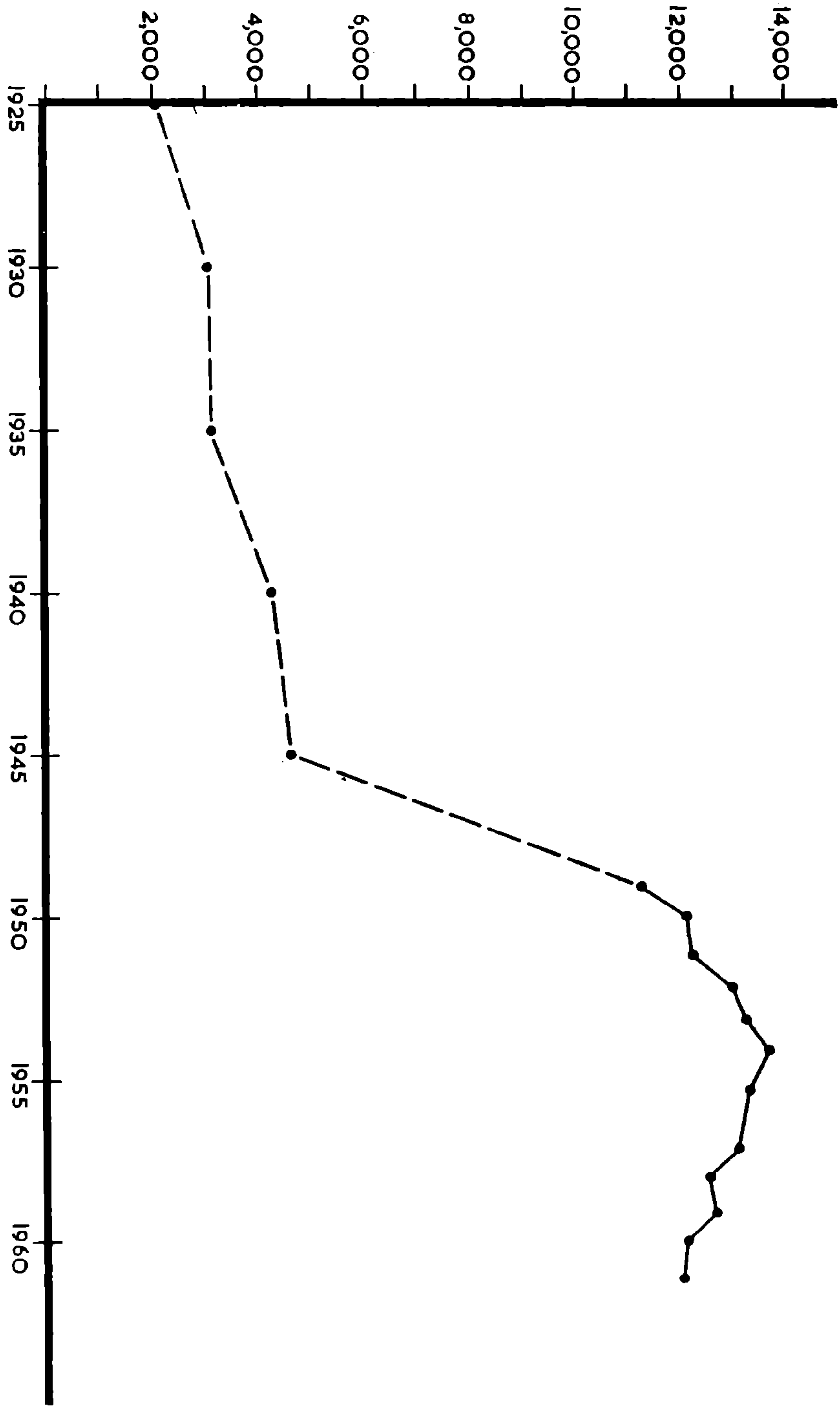

FIGURE 18. Changes in Numbers of Industrial Workers.

FIGURE 19. Approximate Situations of Experimental Areas mentioned in Appendix I.

APPENDIX I

Main Experimental Projects and Localities

While most of the investigations and experiments of the Research Directorate are scattered throughout forests all over the country, there are certain areas where work on some projects is more concentrated. These are listed below; and the approximate position of the forest will be found on the map on page 181, by reference to the numbers given in brackets.

NURSERY EXPERIMENTS

Benmore Nursery, near Dunoon (Argyll) (33)
Bramshill Nursery (Hampshire) (91)
Bush Nursery, near Edinburgh (36)
Fleet Nursery, Gatehouse of Fleet (Kirkcudbright) (46)
Inchnacardoch Nursery, near Fort Augustus (Inverness) (19)
Kennington Nursery, near Oxford (84)
Newton Nursery, near Elgin (Moray) (8)
Sugar Hill Nursery, Wareham (Dorset) (105)
Tulliallan Nursery, near Alloa (Fife) (32)

AFFORESTATION EXPERIMENTS ON PEAT

Achnashellach Forest (Wester Ross) (12)
Beddgelert Forest (Caernarvon) (54)
Inchnacardoch Forest (Inverness) (19)
Kielder Forest (Northumberland) (42)
Naver Forest (Sutherland) (110)
Strathy Forest (Sutherland) (1)
Watten (Caithness) in conjunction with Department of Agriculture and Fisheries for Scotland (2)
Wauchope Forest (Roxburgh) (39)
Also on Lewis, Outer Hebrides and Hoy, Orkney Islands.

FOREST NUTRITION

Allerston Forest, Broxa (Yorkshire) (49)
Culbin (Moray) (5)
Exeter Forest (Devon) (106)
Inchnacardoch Forest (Inverness) (19)
Tarenig Forest (Cardigan) (65)
Wareham Forest (Dorset) (105)
Wilsey Down Forest (Cornwall) (107)

AFFORESTATION EXPERIMENTS ON HEATHLAND

Allerston Forest, Harwood Dale (Yorkshire) (49)
Allerston Forest, Wykeham and Broxa (Yorkshire) (49)
Land's End Forest, Croft Pascoe (Cornwall) (109)
Taliesin Forest (Cardigan) (64)
Teindland Forest (Moray) (11)
Wareham Forest (Dorset) (105)

CONVERSION OF COPPICE

Alice Holt Forest, Marelands (Hampshire) (93)
Cranborne Chase (Dorset) (100)
Forest of Dean, Penyard and Flaxley (Herefordshire & Gloucestershire) (81)

PROVENANCE EXPERIMENTS

Scots pine:	Findon Forest (Easter Ross) (6) Thetford Chase (Norfolk) (67)
Lodgepole pine:	Achnashellach Forest (Wester Ross) (12) Allerston Forest, Wykeham (Yorkshire) (49) Ceiriog Forest (Denbigh) (56) Clocaenog Forest (Denbigh) (52) Millbuie Forest (Easter Ross) (9) Taliesin Forest (Cardigan) (64)
European larch:	Coed-y-Brenin (Merioneth) (57) Mortimer Forest (Herefordshire) (71) Savernake Forest (Wiltshire) (90)
European and Japanese larches:	Clashindarroch Forest (Aberdeen) (17) Drummond Hill Forest (Perth) (23) Lael Forest (Wester Ross) (3)
Douglas fir:	Glentress Forest (Peebles) (37) Land's End Forest, St. Clement (Cornwall) (109) Lynn Forest, Shouldham (Norfolk) (62) Mortimer Forest (Shropshire) (71)
Norway and Sitka spruces:	Newcastleton Forest (Roxburgh) (41) The Bin Forest (Aberdeen) (15)
Sitka spruce:	Clocaenog Forest (Denbigh) (52) Glendaruel Forest (Argyll) (31) Kielder Forest (Northumberland) (42) Mynydd Ddu Forest (Monmouth) (79) Radnor Forest (Radnor) (69) Taliesin Forest (Cardigan) (64) Wilsey Down Forest (Cornwall) (107)
Beech:	Queen Elizabeth Forest (Hampshire) (99) Savernake Forest (Wiltshire) (90)

PRUNING EXPERIMENTS

Drummond Hill Forest (Perth) (23)
Monaughty Forest (Moray) (10)

PLANTING EXPERIMENTS ON CHALK DOWNLANDS

Friston Forest (Sussex) (102)
Queen Elizabeth Forest (Hampshire) (99)

ESTABLISHMENT OF OAK

Dymock Forest (Gloucestershire and Hereford) (80)
Forest of Dean (Gloucestershire and Hereford) (81)

POPLAR TRIALS AND SILVICULTURAL EXPERIMENTS

Bedgebury Forest (Kent) (96)
Blandford Forest (Dorset) (101)
Cannock Chase (Staffordshire) (60)
Creran Forest (Argyll) (22)
Doncaster Forest (Yorkshire) (51)
Dyfnant Forest (Montgomery) (59)
Forest of Dean (Gloucestershire) (81)
Lynn Forest, Gaywood (Norfolk) (62)
Quantock Forest (Somerset) (94)
Rogate Forest (Hampshire) (98)
Stenton Forest (East Lothian) (35)
Wentwood Forest (Monmouthshire) (87)
Wynyard Forest (Durham) (47)
Yardley Chase (Bedfordshire & Northamptonshire) (73)

SPECIES PLOTS

Beddgelert Forest (Caernarvon) (54)
Bedgebury Forest (Kent) (96)
Benmore Forest (Argyll) (33)
Minard Forest, Crarae (Argyll) (28)
Thetford Chase (Norfolk) (67)
Wareham Forest (Dorset) (105)
Cairn Edward Forest (Kirkcudbright) (43)
Kielder Forest (Northumberland) /42)
Dovey Forest (Merioneth and Montgomery) (58)
Mynydd Ddu (Brecon and Monmouth) (79)
Pembrey Forest (Carmarthen) (82)
Tintern Forest (Monmouth) (83)
Coed Morgannwg (Glamorgan) (85)
Brechfa Forest (Carmarthen) (78)
Caeo Forest (Carmarthcn) (76)
Forest of Dean (Gloucestershire) (81)
Bodmin Forest (Cornwall) (108)
Brendon Forest (Somerset) (95)
New Forest (Hampshire) (104)
Micheldever Forest (Hampshire) (92)
Aldewood Forest (Suffolk) (72)
Thetford Chase (Norfolk) (67)

SPACING EXPERIMENTS

Mortimer Forest (Hereford and Salop) (71)
Allerston Forest (Yorks) (49)
Thetford Chase (Norfolk) (67)
Aldewood Forest (Suffolk) (72)
Forest of Dean (Gloucestershire) (81)
Clocaenog Forest (Denbigh and Merioneth) (52)
Kerry Forest (Montgomery) (66)
Myherin Forest (Cardigan) (68)
Tintern Forest (Monmouth) (83)
Ebbw Forest (Monmouth) (86)
Crychan Forest (Brecon) (75)
Coed Morgannwg (Glamorgan) (85)
Caeo Forest (Carmarthen) (76)
Brechfa Forest (Carmarthen) (78)
Brecon Forest (Brecon) (77)
Drumtochty Forest (Kincardine) (21)
Fleet Forest (Kirkcudbright) (46)
Dalbeattie Forest (Kirkcudbright) (45)

UNDERPLANTINGS

Exeter Forest (Devon) (106)
Dymock Forest (Gloucestershire) (80)

COMPARISON OF SPECIES

Gwydyr Forest (Caernarvon) (53)
Forest of Dean (Gloucestershire) (81)
Thetford Chase (Norfolk and Suffolk) (67)
Brechfa Forest (Carmarthen) (78)
Glentress Forest (Peebles) (37)
Glen Urquhart Forest (Inverness) (16)
Benmore Forest (Argyll) (33)
Cairn Edward Forest (Kirkcudbright) (43)
Achnashellach Forest (Wester Ross) (12)

LONG-TERM MIXTURE EXPERIMENTS

Gisburn Forest (Yorkshire) (50)

ARBORETA

Bedgebury Pinetum (Kent) (96)
Westonbirt Arboretum, Nr. Tetbury (Gloucestershire) (89)
Whittingehame Garden (East Lothian) (34)

RE-AFFORESTATION EXPERIMENTS

Forest of Ae (Dumfries) (40)
Newcastleton Forest (Roxburgh) (41)
Thetford Chase (Norfolk and Suffolk) (67)

GENETICS

PROPAGATION CENTRES

Alice Holt (Hampshire) (93)
Bush Nursery (near Edinburgh) (36)
Grizedale Nursery (Lancashire) (48)
Kennington Nursery (near Oxford) (84)
Westonbirt Arboretum, Nr. Tetbury, (Gloucestershire) (89)

TREE BANKS

Alice Holt (Hampshire) (93)
Bradon Forest (Wiltshire) (88)
Bush Nursery (Nr. Edinburgh) (36)
Newton Forest (Moray) (8)
Aldewood Forest (Suffolk) (72)

SEED ORCHARDS

Newton Forest (Moray) (8)
Ledmore Forest (Perth) (24)
Drumtochty Forest (Kincardine) (21)
Stenton Forest (East Lothian) (35)
Alice Holt (Hampshire) (93)
Bradon Forest (Wiltshire) (88)
Forest of Dean (Gloucestershire) (81)
Aldewood Forest (Suffolk) (72)
Lynn Forest (Norfolk) (62)

CROSSING EXPERIMENTS

Allerston Forest, Wykeham & Harwood Dale (Yorkshire) (49)

PROGENY TRIALS

Alice Holt Forest (Hampshire) (93J
Clocaenog Forest (Denbigh) (52)
Chillingham Forest (Northumberland) (113)
Chilterns Forest (Bucks) (114)
Coed-y-Brenin Forest (Merioneth) (57)
Devilla Forest (Fife and Clackmannan) (32)
Farigaig Forest (Inverness) (111)
Forest of Dean (Gloucestershire) (81)
Glenlivet Forest (Banffshire) (112)
Gwydyr Forest (Caernarvonshire) (53)
Kilmichael Forest (Argyllshire) (25)

Kilmory Forest (Argyllshire) (28)
Saltoun Forest (East Lothian) (34)
Stenton Forest (East Lothian) (35)
Teindland Forest (Moray) (11)

TREATMENT OF SEED STANDS

Thetford Chase (Norfolk and Suffolk) (67)

PATHOLOGICAL RESEARCH AREAS

ELM DISEASE TRIALS

The King's Forest (Suffolk) (70)
Kesteven Forest (Lincs. and Rutland) (61)
Huntingdon Forest, Ettisley Wood (Huntingdonshire) (74)

TOP DYING OF NORWAY SPRUCE

Knapdale Forest (Argyll) (29)

FOMES ANNOSUS

The Bin Forest (Aberdeen) (15)
Lael Forest (Ross) (3)
Thetford Chase (Norfolk and Suffolk) (67)
Kerry Forest (Montgomery) (66)
Clocaenog Forest (Denbigh) (52)

BACTERIAL CANKER OF POPLAR

Aldewood Forest, Fen Row Nursery (Suffolk) (72)
Lynn Forest, Gaywood Nursery (Norfolk) (62)
Thetford Chase, Mundford Nursery (Norfolk) (67)

RHIZINA UNDULATA—GROUP DYING OF SITKA SPRUCE

Muirburnhead (Buccleuch Estates) Co. Ltd., (Dumfriesshire) (44)

KEITHIA THUJINA TRIALS ON WESTERN RED CEDAR

Alice Holt (Hampshire) (93)
Ringwood Nursery (Dorset) (103)
Sugar Hill Nursery, Wareham Forest (Dorset) (105)

PINE CANKER CRUMENULA SORORIA

Ringwood Forest (Hampshire and Dorset) (103)

ENTOMOLOGY

PINE LOOPER MOTH

Culbin Forest (Moray and Nairn) (5)
Cannock Chase (Staffs.) (60)

LARCH SAWFLY: ANOPLONYX DESTRUCTOR

Drumtochty Forest (Kincardine) (21)
Mortimer Forest (Hereford and Salop) (71)

SPRUCE APHID: NEOMYZAPHIS ABIETINA

Inverliever Forest (Argyll) (25)
Dovey Forest (Merioneth and Montgomery) (58)
Bramshill Forest (Hampshire) (91)
Alice Holt Forest (Hampshire) (93)
New Forest (Hampshire) (104)

MENSURATION AREAS

THINNING EXPERIMENTS

(Replicated plots)

Bowmont Forest (Duke of Roxburghe) (38)
Loch Eck Forest (Argyll) (30)
Alice Holt Forest (Hampshire) (93)
Edensmuir Forest (Fife) (27)

(Unreplicated)

Culbin Forest (Moray and Nairn) (5)
Achvochkie Forest (Seafield Estate) (Moray) (13)
Kurrwood Forest (Seafield Estate) (Moray) (13)
Deer Park (Crown Woodlands) (Moray) (7)
Glentress Forest (Peebles) (37)
Drumtochty Forest (Kincardine) (21)
Ardgartan Forest (Argyll) (26)
Forest of Ae (Dumfries) (40)

APPENDIX II

Staff engaged in Research and Development

as at 31st March, 1963

The staff listed here are engaged wholly or in part in research and development. Where not indicated otherwise, staff belong to the Directorate of Research. For convenience, staff attached to certain sections belonging to the Headquarters organisation are included, since part of their activities are considered research or development, and these are recorded in the Report on Forest Research.

An asterisk (*) indicates an Assistant Forester.

FOREST RESEARCH STATION: Alice Holt Lodge, Wrecclesham, Farnham, Surrey.
Tel. Bentley 2255

A. Watt, C.B.E., B.A.	Director
R. F. Wood, B.A., B.Sc.	Conservator
T. D. H. Morris	Senior Executive Officer
Miss O. A. Harman	Clerical Officer (Director's Secretary)

SILVICULTURE (SOUTH)

R. M. G. Semple, B.Sc., Head of Section	District Officer
J. M. B. Brown, B.Sc., Dip.For.	District Officer (Ecologist)
J. R. Aldhous, B.A.	District Officer
M. Nimmo	District Officer
A. I. Fraser, B.Sc.	District Officer
J. Jobling, B.Sc.	District Officer

Office:

C. Ridley	Executive Officer
A. Taggart	Clerical Officer
D. J. Baker	Clerical Assistant
Miss E. Burnaby	Scientific Assistant

Research Foresters: Alice Holt

R. Hendrie (Head Forester, South-East Region)
P. W. W. Daborn, A. J. A. Graver*, A. Sibbick.*
D. A. Cousins (Head Forester, South West Region)
Special duties: J. B. H. Gardiner (Wind Studies)
R. W. Genever (Utilisation)
B. C. Howland (Ecology)

Research Foresters: Outstationed

Regions and Areas		*Centre*
Kennington (Oxford)	W. G. Gray, B.E.M. (Head Forester), A. W. Cooke, F. R. W. Stevens*, C. Webber	Kennington Nursery
East Anglia	D. G. Tugwell, G. F. Farrimond*	Santon Downham
Bedgebury Area (S.E. Region)	A. W. Westall, R. E. A. Lewis	Bedgebury Pinetum
Westonbirt Area (S.W. Region)	E. Leyshon, D. J. Rice*	Westonbirt Arboretum
Dean Forest and South Wales	F. Thompson, R. M. Keir* M. L. Pearce*	Lightmoor, Glos.
Mid-Wales	R. M. Ure, P. A. Gregory*, J. E. White*	Knighton
North Wales	G. Pringle, G. A. Bacon	Betws-y-Coed
Wareham (Dorset)	E. E. Fancy, B.E.M. L. A. Howe, F. S. Smith*	Wareham Nursery
South-west England	K. F. Baker, D. J. Williams*	Exeter

EDINBURGH: Government Buildings, Bankhead Avenue, Sighthill, Edinburgh, 11
Tel: Craiglockhart 4010

SILVICULTURE (NORTH)

M. V. Edwards, M.A., Head of Section	Divisional Officer
R. Lines, B.Sc.	District Officer
S. A. Neustein, B.Sc.	District Officer
D. W. Henman, B.Sc.	District Officer
J. Atterson, B.Sc.	District Officer

Office:

P. Hunter	Executive Officer
D. J. Goddard	Clerical Officer
T. T. Johnston	Clerical Officer
Miss M. E. Grant	Clerical Assistant
Mrs. J. E. Kennedy	Machine Assistant
Miss E. P. Beattie	Shorthand Typist
Mrs. E. A. K. Kavanagh	Typist

Research Foresters: Outstationed

Region	*Area*	*Centre*
North Scotland:		
A. MacDonald (Head Forester)		Fort Augustus
D. C. Coutts*		
G. Bartlett	North Scotland	Ardross
D. L. Willmott*		
J. B. MacNeill*	North-west Scotland	Fort Augustus
Central Scotland		
J. Farquhar, M.B.E. (Head Forester)		Kincardine-on-Forth
J. H. Thomson	East Scotland	Elgin
A. L. Sharpe*		
M. T. T. Phillips (see also Genetics)		
J. C. Keenleyside	Mearns	Drumtochty by Fordoun
A. H. Reid*		
E. R. Robson	Central Scotland	Kincardine-on-Forth
M. Rodgers*		
A. R. Mair	West Scotland	Rashfield by Dunoon
R. B. Angus*		
J. E. Kirby*		
D. K. Fraser	South-east Scotland	The Bush, by Roslin
N. P. Danby*		

SILVICULTURE (NORTH)—*continued*

E. Baldwin	South-west Scotland	Mabie, Dumfries
W. J. Blair*		
A. S. Gabriel*		
North England		
J. Weatherell (Head Forester)		Wykeham, Scarborough
G. S. Forbes	Borders	Kielder by Hexham
I. H. Blackmore		
T. C. Booth	North-east England	Wykeham, Scarborough
M. K. Hollingsworth*		
A. A. Lightly* (see also Genetics)	North-west England	Grizedale, Hawkshead

SEED

G. M. Buszewicz, Mgr.Ing. Head of Section — Senior Experimental Officer

Laboratory: D. C. Wakeman (Senior Scientific Assistant)
Miss L. M. Mc.Millan, T. A. Waddell (Scientific Assistants)
Miss P. Hendrie, Miss R. Crumplin (Laboratory Attendants)

Office: Miss S. B. Page (Clerical Officer)

SOILS

W. O. Binns, M.A., B.Sc. Ph.D. Head of Section	Senior Scientific Officer
W. H. Hinson, B.Sc., Ph.D.	Senior Scientific Officer
R. Kitching, B.Sc., A.R.C.S., Ph.D	Senior Scientific Officer

Research Forester: D. F. Fourt

Laboratory: Mrs. R. J. Fourt (Senior Scientific Assistant)
H. M. Gunston, Miss M. Pedley, Miss J. L. Drury
Mrs. J. H. Snelgrove (Scientific Assistants)

STATISTICS

J. N. R. Jeffers, F.I.S. Head of Section	Principal Scientific Officer
H. G. M. Dowden, B.Sc.	District Officer
D. H. Stewart, B.Sc.	Experimental Officer
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APPENDIX III
List of Publications

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In addition, members of the Research and Development Staff assisted with the review and revision of the following Commission publications which were re-issued during the course of the year ended 31st March, 1963.

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Leaflet No. 2. Revised 1960.
(H.M.S.O. 9d. (1s. 0d.).)

Pine Shoot Beetles.
Leaflet No. 3. Revised 1962.
(H.M.S.O. 8d. (11d.).)

Larch Canker and Dieback.
Leaflet No. 16.
(H.M.S.O. 9d. (1s. 0d.).)

Elm Disease.
Leaflet No. 19. Revised 1962.
(H.M.S.O. 9d. (1s. 0d.).)

Collection and Storage of Acorns and Beech Mast.
Leaflet No. 28. Revised 1962.
(H.M.S.O. 6d. (9d.).)

The Grey Squirrel—A Woodland Pest.
Leaflet No. 31. Revised 1960.
(H.M.S.O. 1s. 6d. (1s. 9d.).)

Tariff Tables.
Forest Record No. 31. Revised 1962.
(H.M.S.O. 2s. 6d. (2s. 10d.).)

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FORESTRY COMMISSION

REPORT ON FOREST RESEARCH

for the year ended March 1964

LONDON
HER MAJESTY'S STATIONERY OFFICE
1965

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The photographs, except where otherwise indicated, are taken from the Forestry Commission's own collection. The line drawings have been supplied by the respective authors.

INTRODUCTION

By ANDREW WATT

Director of Research

Organisation and Staffing

The only major change in organisation during the year was the transfer of Publications to the Research Directorate. Publications is now allied with the Library under Mr. H. L. Edlin. Dr. R. G. Pawsey (Pathology) left to take up an appointment at Adelaide University, and the resulting vacancy had not been filled by the end of the year under report.

As anticipated in the previous *Report*, Mr. J. D. Matthews left to take over the Chair of Forestry in Aberdeen University. Mr. R. B. Herbert was transferred from the Welsh Directorate to Genetics in place of Mr. A. F. Mitchell, who transferred from Genetics to Silviculture. Dr. A. M. Fletcher was recruited to Genetics during the year.

Committees

The Advisory Committee on Forest Research met at Alice Holt in July 1963. The Committee's term came to an end in December 1963 and it was reconstituted in January 1964. The new Committee had not met by the end of March 1964. It is appropriate to regret the absence of a number of valued advisers who gave freely of their time both in Committee and individually. However, the composition of the new Committee gives a welcome measure of continuity.

The Research Directorate continued to be represented on a number of Committees concerned with research in forestry and allied fields.

Conferences and Visits Abroad

In the closing months of the year, a considerable amount of staff time was occupied with preparations for the Forestry Exhibition at Blackbushe, Bramshill Forest, and for a number of international organisations which had arranged to meet in Great Britain during the summer of 1964.

Mr. J. N. R. Jeffers (Statistics) attended the 3rd International Conference on Operational Research in Oslo, and organised the first Conference of the Advisory Group of Forest Statisticians of the International Union of Forest Research Organisations held at Alice Holt in September 1963. Mr. Matthews (Genetics), accompanied by Mr. R. Faulkner and Mr. C. McLean, attended a world-wide meeting in Stockholm on Forest Genetics and Tree Improvement. Mr. Matthews represented the United Kingdom at an Organisation for Economic Co-operation and Development meeting concerned with forest seed and plant certification. Mr. J. N. R. Jeffers (Statistics) spent four weeks on a Department of Technical Co-operation assignment in East Africa.

Visitors and General

National Nature Week brought an unusually high number of visits to the forests in 1963. The Forestry section of the British Association visited forest experiments in Morayshire and nursery experiments at Newton, which were also seen by a party of twelve Members of Parliament.

Representatives of the Timber Growers Organisation took the opportunity of visiting Alice Holt to discuss various aspects of the Research programme, and to see some of the work of the Station.

The Society of Foresters were given a demonstration of the tree-pulling technique used to assess stability and they were also shown experiments in the Tweed valley. Members of the Royal Scottish Forestry Society visited mixture experiments at several forests.

Parties from the Universities of Aberdeen, Edinburgh, Strathclyde, Hull, Leeds, Oxford and Wales (Bangor) toured experimental areas, and research workers from several of these were given the usual facilities for detailed investigations. Educational visits were paid by twenty-three schools and five training colleges.

Foreign visitors included representatives from Canada, U.S.A., Australia, New Zealand, Sudan, Spain, Norway, Denmark, Finland and from the French National School of Forestry at Nancy.

Close contacts were maintained with the Nature Conservancy and the Hill Farming Research Organisation. Considerable help and advice was provided by the Macaulay Institute and the Meteorological Office and is gratefully acknowledged.

Lectures were given to Forestry Societies at the Universities of Aberdeen, Edinburgh and Hull, to the Royal Scottish Forestry Society and the Royal Forestry Society of England and Wales, and to various clubs and schools, including a course of six lectures at Gordonstoun.

Work Study Section played an important part in organising demonstrations in connection with National Productivity Year.

REVIEW OF THE YEAR'S WORK

By R. F. WOOD

Conservator, Research Directorate

Previous numbers of this Report have carried a Summary of Parts I and II. As these are essentially accounts of progress and therefore the treatment is somewhat cursory, it is thought that formal summarisation is hardly necessary. The Summary is replaced by a Review, which allows of rather freer comment. Otherwise there is little change in the make-up of the *Report.*

The Season

The effects of the severe winter of 1962/63 were not fully apparent till the late spring of 1963, when the extent of dieback or outright kill of young trees (especially in the south-west of Scotland) could be more readily assessed. The spring and summer of 1963 were cool and moist, there being no spring frosts of note. June provided the only good summer weather. The winter of 1963/64 was open and mild, and free from serious gales. Rainfall was curiously distributed, November being extremely wet, whereas December, January and February taken together represented the driest winter in England and Wales for over 200 years.

PART 1

Forest Tree Seed

A high proportion of the work of the Seed Section is service in the procurement, supply, storage and testing of seed. The main statistics for these types of work are given. Lodgepole pine remains our chief anxiety; it is difficult to work up a reserve, and we cannot obtain the provenances we require for certain special planting conditions.

Research work on seed storage, seed testing methods, and pretreatment and packing techniques is briefly reported. When the new seed extractory at Alice Holt comes into operation in the near future, there will be a need for some developmental work on extraction methods.

Nursery Investigations

This Report has not for some years reflected the full effort in nutritional work of the joint Rothamsted/Forestry Commission experimental programme. Priority has instead been given to the completion of Bulletin 37, entitled *Experiments on Nutrition Problems in Forest Nurseries*, the comprehensive account by Miss Benzian of the work between 1945 and 1962. With the publication of this Bulletin there should be some reconsideration of the direction of nursery research.

A few marginal enquiries in nursery nutrition have been carried on outside the joint Rothamsted/Forestry Commission programme. Mentioned here are fertilizer damage and season of transplanting; magnesium deficiency in pines; 'slow' forms of nitrogen; and long-term fertility experiments. Regarding the latter, several experiments have suggested advantages in organic or mixed fertilizer/organic manuring over straight fertilizers, so far as the growth of seedlings is concerned. None of these experiments has been critical enough to assess fully the nutritional role of the organic manure as distinct, say, from possible physical or biological benefits. The results may be regarded as a confirmation of existing practice, which has been for many years to apply hops and fertilizers to the seedbed in the acid heathland type nursery. The use of organic manures in the seedbed however almost invariably depresses germination rate to a significant extent and, unless the organic manure is the critical factor in raising one-year seedlings to the usable level of height, its main economic effect may be to depress slightly the yield of usable seedlings per unit area and greatly increase the cost of their production. There is probably more justification for the application of organic manures to transplants.

Work on herbicides, which has proved a most profitable field in the past, continues. Paraquat, which also seems likely to have application in the forest, is most promising as a pre-emergent treatment to seedbeds, and is to have extensive user trials. Post-emergence weed control is a more difficult problem since higher degrees of selectivity are called for. There appears to be nothing in sight at the moment to replace or improve on the white spirits. The residual herbicide simazine is now used successfully and on a considerable scale in production nurseries. So far it has appeared extremely safe, but special plots are being laid down to study residues.

Stocktaking methods in nurseries are under review. There is no doubt that great improvements can be effected here, fuller information being obtained at less cost by more advanced sampling technique. This is one of the fields where it is obviously possible to transfer the 'national arithmetic' to the computer, should the balance of advantages point that way.

Silvicultural Investigations

Practically all the investigations under report (except those on the use of herbicides) are long-term, and hence there is no dramatic change in subject matter from year to year. There is a continuing trend to closer study of the environment in all its aspects; in this the Soils Section works intimately with Silviculture.

Some ten years' work on the establishment of shelterbelts in the Shetlands has now been published. This is a field in which forestry, agriculture, and meteorology link up.

The mention of 'industrial sites' indicates that tree planting is often one of the factors in restoration. While no considerable amount of research can be carried out, an effort is made to collect experiences and some knowledge of the site factors concerned in order to help those concerned with restoration.

Amelioration of forest sites remains, and will continue to be, one of the largest project groups. In forest manuring, it seems clear that the pole crop is not a stage at which the largest responses to fertilizers are to be expected. Recent indications are that older crops may be a more favourable subject. Potassium deficiency, which has been known on deep acid peats in Scotland now seems likely to be of some importance in established spruce crops in Wales.

Experimental cultivations have usually indicated increasing benefits the more drastic the site preparation. A paper by D. W. Henman in Part III of this *Report*, entitled *Some Early Responses to Increased Intensity of Heathland Cultivation*, deals more fully with this topic. Physical imperfections of one sort or another being so common in our soils, the question of the limits of improvement in cultivation and drainage is of the first importance.

Most work on regeneration continues to be on replanting. An important pioneer experiment on the size of felling area is described by S. A. Neustein in Part III under the title *Windthrow on the Margins of Felling Areas.* It is somewhat ironic that natural regeneration of Sitka spruce occasionally appears in experiments where it is not wanted in quite prolific quantities, in spite of the fact that the parent crops are of no great age. It is becoming evident that it cannot be dismissed as a method. Direct sowing experiments may tell us more about the seedbed requirements of the tree.

In several forests, fellings for normalisation or to 'cash in' on unproductive crops have given the opportunity for regeneration studies including experiments in underplanting pines and larches. At Thetford, one of the chief interests is in the relative resistance to *Fomes annosus* of alternative species to pines, notably *Abies* species.

Provenance studies on most of the principal species are fairly advanced, and much recent attention has been given to seed sources for the special conditions in the North and at high elevations. In the severe winter of 1962/63 Sitka spruce of Alaskan seed source remained relatively undamaged on certain Scottish sites where the standard Queen Charlotte Islands stock suffered severely. In Lodgepole pine, our knowledge of provenance attributes is unfortunately not equalled by our ability to obtain the seed we want. For the exposed conditions and poor soils of the far north it is known that we should obtain seed from higher latitudes on the Pacific coast.

Certain of the modern herbicides appear to have found their applications in the forest, notably 2, 4, 5-T and ammonium sulphamate. The quick-acting herbicide paraquat seems likely to be useful in weeding plantations, especially on very grassy sites, but it is possible that its most useful role will be as a desiccant, making it easy and safe to burn fire traces whilst the surrounding vegetation is still green.

The problems of windthrow of crops continue to be studied from a variety of aspects. The 'tree-pulling' technique has been used to study the effects of soil type and also of spacing and thinning on the resistance of trees to uprooting. That closely-spaced trees should root more deeply than wider spaced ones on a poorly drained soil was something of a surprise. If, as seems likely, it has a hydrological explanation, it offers encouragement to the idea of permanent improvement of ill-draining soils by the interaction of transpiration and surface drainage. One might speculate how far such an effect could extend; would for instance dense natural regeneration on ill-draining soils have a marked advantage in depth of rooting over normally spaced plantations?

A good deal of attention has been given recently to the malaise (if the term is not begging the question) of spruce crops on what are regarded as marginal sites. Various unpleasant symptoms have been observed: cessation of height growth with deformation of the leader ('bent top'); loss of crown density; and *Neomyzaphis* infestation associated with reduction of volume increment. The limits of an exotic are apt to be pathologically defined and the various symptoms are only important in so far as they help in diagnosing the deficiencies of the environment.

Poplars and Elms

It is becoming increasingly clear that balsams and hybrid balsams provide the fastest growing poplar clones for British conditions, and verv markedlv so under the less favourable climatic conditions of the north and west. Hence it is encouraging that peeling tests of some of the first available trees of the fastest clones under trial have indicated good veneering properties. In experiments on the pruning of poplars, the use of vernier girth bands has allowed the effects of pruning intensity on radial increment to be observed during a single growing season. The research forester traditionally observes the effects of treatments over seasons, when relatively coarse measurements will serve. There are, however, a number of fields in which more delicate instrumentation will economise in the time required to produce information, or will reveal patterns which are not obvious on the larger scale.

One of the important aspects of the work on elms is the conservation of the best of the variants and hybrids among the native elm populations; this is timely, because the demand for elm timber is selective and there has been a considerable risk that some valuable genotypes might disappear. Fortunately elm lends itself to the technique of mist propagation. Useful progress has been made in testing the types of vegetatively-produced stock and in elm, rooted cuttings transplanted for one year proved excellent stock for woodland planting and in fact superior to more expensive older transplants. Testing of selected clones for susceptibility to Dutch elm disease is carried out in collaboration with the Pathology Section, and close contacts are maintained with the Dutch elm breeders. A collection of superior clones is being established at Westonbirt Forest in Gloucestershire.

Forest Ecology

Much of the Ecologist's time has been spent on completing his study of *Pinus nigra* in Britain. He has also been involved in field studies in South Wales, where there has been some anxiety about the continued performance of Sitka spruce on certain sites.

Forest Soils

Having recently taken over the forest fertilization experiments from Silviculturist (South), much time has been spent on a general review of the work. (The nutritional work of the Soils Section is in fact reported under Silvicultural Investigations). The investigations on soil moisture using resistance blocks have been continued and extended to the sands overlying the Chalky Boulder Till at Thetford Chase in East Anglia. Here one of the chief objects of interest will be the relative behaviour of pure pine and pine underplanted with beech. In the first year of observation little difference in the drying rates in the profile appeared. The Chalky Till itself is a very different medium to the sand, much more conductive of moisture. On the original site at Bramshill Forest in Hampshire (Bagshot Sands), the comparison of soil-drying patterns below Corsican pine and Douglas fir again strongly indicated that the Corsican pine was 'using' more water. In common forestry parlance moisture requirement is judged by the apparent climatic and soil predilections of the species. The picture may have little relationship to the actual water economy of the trees.

The Section is also much concerned with drainage, and collaborates with Silviculture in looking after the hydrological aspects of forest drainage experiments. That at Halwill, Devon (Culm Measures), has now been fitted out with recording flow gauges at the outfall drains.

Forest Genetics

The survey of home seed sources is a continuing task. Recently a great deal of attention has been paid to Lodgepole pine, in view of the difficulties experienced in importing seed of certain desirable provenances. Work has also been done on the *Register of Seed Sources*, which is the key document for home seed collection. A more realistic approach to registration has been adopted, as too many mature stands unsuited for management and presenting difficulties for collection have found their way to the register. An improved format and classification have now been adopted.

The selection of Plus trees is a basic activity. In Sitka spruce candidate trees which have already been subject to a very stringent selective procedure are studied (by means of extracted cores) for density and tracheid length at the Forest Products Research Laboratory, Princes Risborough. The general aim in Sitka spruce is to improve the form and yield of the tree whilst maintaining or slightly improving the intrinsic qualities of density and tracheid length.

Work on propagating techniques continues, but the problem of rooting Sitka spruce from cuttings remains obdurate. This is one of the fields where the work of the plant physiologist can be of immediate practical value (see Wareing and Smith page 130).

The older seed orchards (larch and Scots pine) now allow controlled pollination and progeny testing to be carried on as flowering permits. A review of the seed orchard work undertaken to date will be found in Part III.

Forest Entomology

The 'early warning system' of pupal counts had prepared us for a serious infestation of *Bupalus* at Cannock Chase in Staffordshire. Aerial spraying was resorted to as an emergency measure to avert widespread deaths from secondary insect attack. The operation was organised as a co-operative enquiry with Nature Conservancy and the spraying contractors into the possible side effects of D.D.T. on wild life. At a forest like Cannock, such measures are regarded as affording a measure of time (ten to twelve years or so) during which progress can be made in the change of species to a less susceptible crop. The idea of propping up a species by repeated spraying remains in disfavour, though it is conceded there may be a case for it where the protective role of the forest is high.

Mammals

From work in Scotland it now seems probable that it will be practicable to control Grey squirrels by poisoning with the well-known rodenticide 'Warfarin'.

The value of cage trapping just before the period of damage as a protective measure in vulnerable crops has been further confirmed. If (as most informed people will now accept) we have to learn to live with the Grey squirrel, it is such measures—aimed at reductions of the population locally where and when damage is feared—that will have to be learned and practised.

More work has been done on repellents—substances intended to deter animals and birds from eating seed or browsing foliage or rubbing stems, etc. The subject bulks quite large in the literature—the objectives are very attractive but on the whole the promise in British investigations has been rather small.

Forest Pathology

The root and stem rotting fungi remain the most important subjects of study—especially *Fomes annosus*, though there are other fungi which might well warrant equally thorough attention. The general attack on *Fomes* has been a most profitable example of the collaboration of university and governmental research, since the studies of Dr. Rishbeth of Cambridge University played a key role in the development of practical measures on control. At present, the use of the competing fungus *Peniophora gigantea* as a measure of biological control against *Fomes* is one of the most interesting and promising approaches, though this fungus is unfortunately confined to the pines. This method does, of course, raise problems of the production of the fungus in culture in considerable quantities, though probably at a scale insufficiently interesting to the firms of importance in the antibiotic field.

Many, if not most of the investigations in hand have close links with the work of other sections. Work on elm disease and bacterial canker of poplar relates to the selective work on these genera in Silviculture; studies on the site factors conducive to stem crack in *Abies grandis* link with the joint Forestry/Forest Products Research Laboratory programme on home-grown timbers.

Both the protective sections, Entomology and Pathology, receive increasing numbers of enquiries from Commission and private sources. This can be regarded as an essential part of the communication net, but there is a risk that research may suffer if the advisory work is allowed to get out of balance.

Planning and Economics

This Headquarters section carries out certain items of research in addition to its routine duties. The important field of Mensuration is included. Thinning research is becoming more intensive; in one experiment the reactions of individual trees are being measured at weekly intervals. An effort is being made to use very young plants (nursery transplants) as material for thinning experiments, following Japanese examples. If such small trees can be shown to represent older crops to any important extent, the advantages are obvious.

The activity of soil surveying in connection with the preparation of working plans of necessity produces information on the relationships between site and tree behaviour. A special, and most important aspect of this work is the survey of forests on soils conducive to windthrow, and here close contact is maintained with the Silviculturists working on this problem.

Work Study

Most of the teams have continued to work on production operations in pulp, pitwood, etc., the trend being to make comprehensive studies of operations from the 'stump to the factory' (or at least to the final unit of haulage). Work Study is thus increasingly concerned with machinery for extraction, loading, and haulage; and it is a rather small step from studying the best way of organising work around some accepted machine, to comparing machines and initiating developments in others.

Work Study has begun to turn its attention to silvicultural operations. This raises some very intriguing questions. Whereas in production the final specification is either fixed or varies between set limits, in many silvicultural operations this is far from the case; the plantation for instance requires weeding but to what degree is uncertain; nor is it possible to decide such points for a multiplicity of types by empirical experiment. It is possible Work Study will do a great deal of good by simply questioning accepted practices, and there appears to be a wide field for joint studies with Silviculture.

Utilisation Development

The Marketing Section at Headquarters, in addition to its wide range of routine functions, carries out a few enquiries by itself; but in research it is principally concerned with the joint programme on home-grown timbers with the Forest Products Research Laboratory (Department of Scientific and Industrial Research), Princes Risborough. Here work on the larches has indicated that there is little difference between European and Japanese species—as timbers. It will be useful if it can be found that other timbers can be 'grouped', since one curse of marketing in this country is that there are so many things coming in penny packets. Another curse is the poor seasoning of so much home-grown timber. The development at Princes Risborough of a simple cheap kiln may well be an important project.

Increasing attention is given to outlets for the timbers at present difficult to market profitably, such as low-grade hardwoods.

Machinery Research

A high proportion of the work is concerned with the development of machines for extraction and loading, as would be expected in view of the rapidly increasing programme of thinning in Commission forests. British forestry can hardly be said to provide a mass market for machinery, so it is of interest that one tractor designed specifically for forestry (in Britain) is coming along.

Design and Analysis of Experiments

This was the first full year's experience of the Station's own electronic computer (an International Computers and Tabulators Sirius) entailing a good deal of necessary development and reorganisation. While the numbers of analyses continue to mount, the main increases are in the more complex analyses, rather than in the routine computations, etc., from experimental data. It is gratifying (though slightly alarming from a research point of view) to note the speed at which applications of the computer are being found in the fields of management and administration.

The Statistics Section has become recognised as a training centre for vacational work for Diploma in Technology, etc. students, the great variety of material available in forestry being an especial advantage. The section is probably more concerned than any other in providing technical assistance to forestry departments abroad, especially those in the less developed territories.

Photography

Loans of colour slides for lecturing, etc., have risen from 650 to 17,000 per annum in the last ten years. Colour is also used increasingly in publication. It has not been possible to do much filming recently but it is hoped to make a modest restart on training films in the near future.

Publications and Library

These two activities were combined into one section during the year. Both of course are concerned with the Commission as a whole and not purely Research.

PART II

As usual this is given to progress reports on research supported by Forestry Commission grants at universities and other institutions. Authors' summaries are appended to the reports, where these are long enough to call for them.

The work on Scottish soils described by H. G. Miller and R. C. Mackenzie of the Macaulay Institute at Aberdeen continues the long-standing arrangement for research and advisory services at that institute. The main emphasis is on the peats and the poorest mineral soils.

From Rothamsted Experimental Station, Miss B. Benzian contributes a short report on one particular aspect of the nursery nutritional work which has been the subject of a long period of collaborative work between Rothamsted and the Commission. An account of the work between 1945 and 1962 will shortly be published as Forestry Commission Bulletin No. 37 entitled *Experiments on Nutrition Problems in Forest Nurseries.* Also at Rothamsted, Dr. G. A. Salt has used partial soil sterilisation in studying pathogenic soil organisms, one of the more difficult side issues of the main nutritional programme.

There follows a group of reports on various aspects of soil biology or biochemistry. These are all fundamental studies aimed at obtaining a better understanding of soil-forming processes and the role of various organisms in the breakdown of forest litter. Dr. G. W. Heath, of Rothamsted, is mainly concerned with earthworms; Dr. D. R. Gifford of the Department of Forestry and Natural Resources, Edinburgh University, has studied the micro-arthropods and his work links up closely with that of Dr. Hayes (also of Edinburgh) who is examining the role of fungi in the breakdown of Scots pine litter. Dr. J. Tinsley of the Department of Soil Science, Aberdeen University, has been studying the changes in the forest litter of Scots pine consequent on various manurial treatments (nitrogen forms and liming).

At the Department of Forestry, Oxford, Dr. L. Leyton and Dr. E. R. C. Reynolds continue their studies on the hydrological relations of forest stands. The work (which derives its main support from the Department of Scientific and Industrial Research) is of almost equal interest to foresters and hydrologists.

Dr. P. H. Thomas and Mr. D. L. Simms of the Fire Research Organisation, Boreham Wood, Herts., have been conducting basic research on the behaviour and spread of fires in the type of fuels met with in heath and woodland. These researches have reached the point where it will be profitable to relate the laboratory results to field observations.

Mr. D. C. Malcolm and Mr. J. E. Cousens of the Department of Forestry and Natural Resources, Edinburgh University, have completed their present studies on populations of oak in Scotland. Mr. Malcolm reports on oak woods in Galloway, and Mr. Cousens has made a visit to Jugoslavia to check the characters of Pedunculate oak in regions where introgression by Sessile oak seems extremely unlikely. The general conclusion from these studies has been that while Sessile oak is a 'good' species in Britain, Pedunculate oak is very variable and much subject to introgression by Sessile oak.

Professor P. F. Wareing and Mr. N. G. Smith of the Department of Botany, University College of Wales, Aberystwyth, provide a further note on the physiological factors behind the rooting of cuttings. As with earlier work directed by Professor Wareing (on maturity and flowering, etc.) there is little difficulty in perceiving the immediate practical value of physiological studies in this field. It is probable also that empirical experimentation on the improvement of yield could do with some fertilization from basic physiological studies on growth.

Dr. Myles Crook of the Department of Forestry, Aberdeen University, gives a brief statement on the progress of his large-scale experiment on the effects on the Pine-looper populations in Culbin Forest of increasing the breeding numbers of the Coal tit. At this stage the work is still concerned with the habits and movements of the existing tit populations.

Dr. Fairbairn of the Department of Forestry and Natural Resources, University of Edinburgh, gives a short note on his work on the measurement of light intensity. Dr. W. E. S. Mutch, also of Edinburgh, makes an interesting pioneer essay in the evaluation of recreational values in the forest, a subject which will certainly require much attention in the future.

PART III

This part carries papers by Forestry Commission staff (normally) in the form of interim reports on long-term projects, reviews of research in particular fields, notes on methodology, etc.

H. L. Edlin gives an account of the Forestry Commission's Library at Alice Holt. R. G. Pawsey (now of the Waite Agricultural Research Institute, Adelaide) describes experiments in the control of *Didymascella* (*Keithia*) on *Thuja plicata* with the antibiotic cycloheximide. The substance is commercially available in the United States, but has so far found no important applications here, and though obviously useful in this particular role, seems unlikely to be worth marketing for such a restricted purpose.

J. Jobling and C. W. T. Young deal with some of the apparent anomalies in the behaviour of clones under trial for susceptibility to the bacterial canker of poplars. It appears likely that part of the trouble is due to the existence of strains of the bacterium of differing pathogenicity, but it has also been found that one of the modes of natural infection, from the tunnelling of *Agromyzid* insects, brings about lesions which heal much less easily than the small scars of experimental inoculation.

S. A. Neustein describes a pioneer experiment in the regeneration of pure spruce in the Borders, dealing with the effect of size of felling coupe on the stability of the margins. One indication is that if it is desired to study irregular stand structure as such it will be necessary to build up such conditions from the time of planting, or by making sacrifices in very young crops, since in these pole stands of Sitka spruce the felling of groups seems likely to be followed by rapid attrition of the margins facing the wind.

D. W. Henman studies the evidence on growth and yield from two of the older experiments comparing intensities of cultivation on heathland soils. Cultivation can be judged at two levels: firstly on the establishment and early growth of the crop, and secondly in terms of the ultimate yield. There seems little reason to doubt that deep complete cultivation will increase yields on many types of heath, but it may very well be that the investment in cultivation will reach a peak before the maximum growth response is reached. We clearly require to know much more about the theoretical potentialities of many of our sites.

R. Lines and A. F. Mitchell give the results of a number of the older provenance experiments in Scots pine. The technique in this type of experiment has greatly advanced since these were laid down, but nevertheless a reasonably clear pattern of result has been obtained. In Scotland there appears to be no case for importing Scots pine seed, but in the South of England yield can be increased by the use of provenances from certain districts of France and Germany.

R. M. G. Semple reviews the evidence from experiments in the removal of bark by chemical means, a technique with possible application in hardwood pulp-wood production. Arsenical salts have been used very successfully for this purpose in other countries, but are not considered safe under British conditions, and so far no other substances have been found which are sufficiently general in application. Even if technically successful, the process seems dubiously economic under our conditions.

P. A. Wardle describes an interesting example of the use of operational research in forest management, the solution of a problem involving a number of interacting alternative choices in the management of the New Forest, by linear programming for the computer.

PART I

Reports of Work carried out by Forestry Commission Research and Development Staff

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FOREST TREE SEED

By G. M. BUSZEWICZ

The year under review marked the first full year of the Seed Section as an independent central unit dealing with seed procurement and supply for the Forestry Commission and for many of the requirements of private forestry. The main effort has been concentrated on the administrative side of the problems, the most important of these being the increase of seed collection at home and the construction of the new seed extractory at Alice Holt.

The research content of the Section's programme is dependent on the weight of work involved in the procurement, extraction, storage, testing and distribution of seed.

Seed Procurement

The season did not give a good crop at home and only 1,225 lbs. of conifer and 387 lbs. of hardwood seed were collected. The main effort was concentrated on registered sources and the amounts collected for main species were as follows:

Conifers	*lbs.*	*Hardwoods*	*lbs.*
Scots pine	374	Sessile oak	100
Corsican pine	230	Beech	75
Lodgepole pine	28	Sycamore	37
Douglas fir	11	Maple	32
Japanese larch	63	Ash	4
Hybrid larch	195	Birch	3
Western red cedar, *Thuja plicata*	10	Alder	20
Noble fir, *Abies procera*	208	Other	116
Lawson cypress	18		
Other	88		
Total	1,225		387

The shortage of seed from home sources forced us to import from abroad 3,841 lbs. of conifer (mainly Lodgepole pine, Norway spruce, European larch and Western hemlock) and 22,199 lbs. of hardwood seed (mainly acorns and beechnuts).

Seed Supply

During the year the seed store despatched 10,399 lbs. of conifer seed, 5,459 lbs. to Commission nurseries and 4,933 lbs. to private forestry. As compared with last year the Commission required 1,000 lbs. less, and private forestry 700 lbs. more; of conifer seed. During the same period 21,570 lbs. of hardwood seed were distributed, 14,794 lbs. to the Commission and 6,776 lbs. to private forestry owners.

Seed Extraction

The new seed extraction plant at Alice Holt (see *Rep. For. Res.* 1963) is in the final stages of completion and the Forest Year 1965 (Autumn 1964 onwards) will be the first operational season. The method of extraction for different species and batches of cones will be prepared as the work proceeds. The plant is illustrated in our Plates.

Seed Storage

The total seed stock held in our refrigerated seed store was 19,663 lbs. covering more or less two years' requirements. The stock varies, however, for individual species and there is a shortage of Lodgepole pine, Japanese larch and Hybrid larch seed. For some time there has been difficulty in obtaining the desired provenance of Lodgepole pine seed from abroad and unfortunately the crops of Hybrid larch at home have been consistently poor.

Research on seed storage is concentrated on those species known to be difficult for long-term storage:

Abies. This experiment is now in its fifth year and the object is to examine the influence of storage atmosphere (hermetic seal, vacuum seal and CO_2 gas seal), seed moisture content (4 – 16%) and storage temperature (−20°C. to +20°C.) on seed longevity. The results after 5 years' storage will be analysed and published elsewhere.

Beech. The experiment, which started in 1960/61, will be concluded next year. Substantial evidence indicates that beechnuts can be stored by the routine procedure for conifer seed for at least three years without deterioration.

Elm. Infrequent seeding and limited storage life of home-produced seed present difficulties in supplying this seed to our nurseries. Small-scale storage trials on home-collected seed are being continued.

In connection with seed storage, mention should be made of two additional items on which work is also continuing:

Seed colouring. Germination tests on stored seed coloured with a range of Waxoline dyes as a cheaper and simpler alternative to the existing practice of dressing with red lead. It is assumed that dressing will eventually be carried out centrally in the seed store and this will involve colouring, and also fungicidal and bird repellant dressings.

Seed packing. Under the present procedure two different types of can are used; one for storage and another for despatching. For despatching, the seed must necessarily be transferred from one container to the other, and it is intended to eliminate this work by introducing a new type of container to serve both purposes.

Seed Testing

The quality of all seed lots in store is examined each year at the Licensed Seed Testing Station inside the Seed Section. During the year under review

1,008 samples were tested and the analysis completed as follows:

Purity tests	468
Seed size determination	527
Germination tests	1,500
Tetrazolium tests	117
Moisture content tests	485
Others	41

These numbers include tests, amounting to about 20% of the whole, carried out in connection with our experimental work, and several tests were performed on samples received from members of the Forest Tree Seed Association.

Research work was centred around our programme for improvement and standardisation of testing methods in collaboration with the International Seed Testing Association. In 1965 the Seed Testing Rules will be revised at the Munich Convention and the proposals are now being prepared. This work involves the reviewing of seed testing methods for 134 species.

Additionally, a number of referee samples were tested by the excised-embryo tetrazolium method and work started on standardising the definition of abnormal seedlings on our germinators.

An interesting device for weighing individual seeds, developed by Forester A. S. Gardiner of the Genetics section, is illustrated in our Plates.

Other Activities

The staff participated in the Annual Conference of Seed Analysts at the National Institution of Agricultural Botany, Cambridge.

NURSERY INVESTIGATIONS

By J. R. ALDHOUS and J. ATTERSON

In the South, the main weight of nursery experimental work remains in the programme on nursery nutrition carried out jointly with Rothamsted Experimental Station. Miss Benzian reports briefly on one aspect of this work in Part II of this issue, and her full account of the experimental work undertaken between 1945 and 1962 has been published as Forestry Commission Bulletin No. 37, entitled *Experiments on Nutrition Problems in Forest Nurseries.* (H.M.S.O., 1965, Vol. I £2 10s. 0d. net, Vol. II—Supporting Tables, £1 0s. 0d. net.)

FACTORS INFLUENCING THE YIELD OF SEEDLINGS

Date of Sowing and Irrigation

Date of sowing was again studied at Kennington, Wareham and Alice Holt. Three species were sown, Sitka spruce, Japanese larch and Western hemlock, and for each species three lots were compared, each lot differing by age or seed origin. This was the third year in which these experiments had been laid down. They were designed to reveal any differences in growth or yield due to storage or origin of seed, and to give a general indication of the effect of date of sowing in each particular year of the experiment.

At each nursery, the first sowings were delayed owing to the cold winter and best yields were obtained from the earliest sowings, which in this year took place in late March to mid-April. Sowings in late May gave very poor results. Analysis of the year's results showed little effect of age or seed origin on growth or yield.

The experiment is due to be repeated for the last time in 1964, after which a full analysis will be made combining the four years' results.

At Kennington, certain plots in the experiment were irrigated, the amount applied depending on the estimated evapotranspiration. All irrigated plots were watered each time irrigation was prescribed but half the plots received half as much water, at each watering, as did the others.

Statistical analysis showed that in this season the increases in height growth and yield due to irrigation were small.

J. R. ALDHOUS

Pretreatment of Seed and Irrigation

A preliminary experiment at Inchnacardoch Nursery on the use of hydrogen peroxide, citric acid and tartaric acid as pre-sowing treatments of Lodgepole pine seed gave some promising results. The Lodgepole pine seed was soaked in the chemicals mentioned at the strengths and for the lengths of time given below:

Strengths of solutions used:

Hydrogen peroxide	—	30%, 10%, 3⅓%
Citric acid	—	1%, 0.33%, 0.11%
Tartaric acid	—	1%, 0.33%, 0.11%
Length of time of soaking:	—	3 hrs., 1 hr., ⅓ hr.

Citric and tartaric acids did not improve either the rate or the percentage germination of the seed, and the former reduced the percentage germination when used at the strongest concentration for the longest period of soaking. Hydrogen peroxide, on the other hand, improved the rate and percentage germination when used at the strongest concentration for the longest period of soaking, but only if the seed bed was watered immediately after sowing (See Table 1).

TABLE 1

GERMINATION OF LODGEPOLE PINE SEED

Percentage of viable seeds sown

Treatment	Watered after sowing		No watering after sowing	
	Weeks after commencement of germination			
	2	10	2	10
Hydrogen peroxide (30% for 3 hours)	49	94	7	45
Soaked in tap water (for 3 hours)	26	74	9	70
No treatment	27	75	13	74

Watering at the rates of ½ and 1 gallon per sq. yd. immediately after sowing improved the rate but not the percentage germination of seed, whether soaked prior to sowing or no. The soil was not dry at the time of sowing, but no rain fell for four days after. Watering at this particular stage has not been tried before, and appears to warrant further investigation.

Prolonged irrigation from spray lines, as distinct from one watering immediately after sowing as reported above, was again tried at Bareagle Nursery in South-west Scotland. As in the previous two years, no differences were apparent between watered and unwatered seedlings, no doubt due to the very wet growing season.

J. Atterson

Bitumen 'Mulches'

Experiments were carried out at Kennington and Alice Holt to evaluate the effect on germination of seedlings and growth of transplants of a layer of bitumen over the soil surface—a bitumen "mulch". The bitumen was provided and applied by Esso Research Ltd., and was sprayed onto the soil or seedbed cover, (a) to form a continuous and more or less waterproof cover (heavy application) and (b) sufficient to colour the soil but not to make a water-proof cover (light application).

Seedbeds were sown with Corsican pine, Sitka spruce, Douglas fir and Western hemlock, either in April or between three and four weeks later.

At both nurseries, the bitumen depressed germination of all species drastically. This result is at variance with reports (unpublished) from Sweden, where Scots pine is said to have responded well to the heavy bitumen application.

On transplants, light and heavy dressings of bitumen were applied to four-inch strips of soil either between or over rows of Japanese larch, Sitka spruce, Corsican pine and Western hemlock. No treatment had any significant effect on survival or growth of any species except Corsican pine. Transplants of this species were checked by the heavy overall application of bitumen.

J. R. ALDHOUS

NUTRITION

Fertiliser Damage to Transplants

In recent years, circumstantial evidence has indicated that where seedlings are transplanted late in the spring, they may be damaged by standard fertiliser applications which would normally not harm them. To obtain further evidence, small trials were laid out at Alice Holt, Kennington and Wareham in which Norway and Sitka spruce and *Abies procera* seedlings were transplanted late in the spring.

At all three nurseries there was a sharp contrast between species, Norway spruce and *Abies procera* showing marked discoloration and browning of foliage on plots given double the standard application of potassic superphosphate. These species on plots given the standard application showed a little discoloration, while untreated plots showed practically none. Discoloration has been observed before on Norway spruce, but this was the first time that damage to *Abies* has been demonstrated in a series of experiments.

J. R. ALDHOUS

Magnesium Deficiency in Pines

The 1963 growing season has been notable, in Scotland at least, for the very marked discoloration of Lodgepole pine and Sitka spruce seedlings, particularly the former, the needles of which in many nurseries turned bright red with yellow tips. This is strongly suggestive of magnesium deficiency, and analysis of the seedlings showed normal concentrations of N, P. K, and Ca, but Mg concentration in the green seedlings was 0·12%, in the yellow seedlings 0·06%; a concentration of 0·10% would be considered adequate.

Sitka spruce seedlings at Fleet and Devilla Nurseries, among others, turned bright yellow at the end of the growing season, also indicating magnesium deficiency. Seedlings from Fleet were analysed and showed adequate concentrations of N and P, but yellow seedlings showed much less K and Mg than the green ones. (K 0·56% as against 1·20%, Mg 0·35% as against 0·80%). Deficiencies of both these elements are likely to be accentuated in a wet summer such as that of 1963.

Spraying of yellowed Sitka spruce seedbeds at Devilla nursery with Epsom salt solution rapidly removed the symptoms. Magnesium deficiency in the seedbed does not usually carry over any serious effects to the second year, but at Devilla, beds not treated with magnesium were damaged by frost during the subsequent winter, whereas treated beds escaped.

Magnesium deficiency is readily prevented by foliar sprays or (where liming is admissible due to the extreme acidity of the nursery) by advance applications of magnesian limestone.

A much more promising source of magnesium, and one which also contains nitrogen and phosphorus, is magnesium ammonium phosphate, and this material was tested during 1963 at five nurseries throughout Scotland. This fertiliser produced larger Sitka spruce seedlings than the normal fertiliser regime (i.e. potassic superphosphate applied before sowing, plus "Nitrochalk" as two top dressings) at one nursery only, namely Fleet. At the four other nurseries the differences between seedlings treated with magnesium ammonium phosphate and the normal fertilisers were slight; but at Fleet, which is the most magnesium-deficient site, the improvement was from less than 1 inch on the normal fertiliser plots to $1\frac{3}{4}$ inches on the magnesium ammonium phosphate plots. The effect of this fertiliser on colour was even more marked, the seedlings treated with magnesium ammonium phosphate being dark green and the seedlings treated with normal fertilisers being bright yellow. Although no height increases were observed at the four other nurseries, seedlings treated with magnesium ammonium phosphate were always darker green.

Forms of Nitrogen

The main object of the series of experiments in which magnesium ammonium phosphate was included was to find a long-lasting source of nitrogen which could be applied before sowing, together with phosphate and potash. This would be an advantage over the present method of applying nitrogen (i.e. as top-dressings during the summer) as this method can cause tissue-burning leading to *Botrytis* fungal infection, and is also more expensive and time-consuming than a pre-sowing application. The types of slow-release nitrogen applied before sowing in these experiments (in addition to magnesium ammonium phosphate) consisted of a N P K granular fertiliser coated with several different water-repellent coats. None of the coats used appeared to work effectively, as the seedlings grown on plots with these fertilisers were not as green at the end of the growing season as seedlings treated with the normal nitrogen top-dressings.

Fertility

In the long-term experiment at Teindland Nursery, in which hopwaste is compared with inorganic fertilisers on annually repeated sowings of Sitka spruce, the hopwaste seedlings continue to compare very favourably in colour and size with the fertiliser ones; seedlings raised on hopwaste plus fertilisers being the best. It seems probable that on this site much of the benefit of hops may lie in nitrogen supply, and variations in the dosage of nitrogen to the fertiliser plots will now be introduced.

J. ATTERSON

WEED CONTROL IN THE NURSERY

Pre-emergence Control of Weeds in Seedbeds

Paraquat

Paraquat was tested as a spray application to seedbeds before the emergence of the sown crop at Kennington, Wareham and Alice Holt. At each site, sprays were applied fourteen days after sowing and also three or four days before expected emergence (at the time of normal pre-emergence spraying with vaporising oil). Plots were sown in bands with Sitka spruce, Japanese larch, Western hemlock and Douglas fir. Paraquat was sprayed at $\frac{1}{2}$, 1, $1\frac{1}{2}$ and 2 lbs. active ingredient in 40 gallons of water per acre. At each nursery, a good control of weeds was achieved by all rates of paraquat, even the lowest rate equalling the effectiveness of vaporising oil. There was no significant damage to crops at any nursery from paraquat at either time of application, but there was a suggestion that paraquat at 1½ and 2 lbs. per acre, applied at the normal pre-emergence date, killed a few seedlings. A pre-emergence spray of paraquat at ½ or 1 lb. per acre costs appreciably less than the standard application of vaporising oil.

Linuron

This herbicide is one of the triazine group, and has both contact and residual action. It was tested for the first time at Kennington at ½, 1, 1½ and 2 lbs. per acre in 40 gallons of water per acre, applied 14 days after sowing and also at the time of a normal pre-emergence spray of vaporising oil. Plots were sown with Sitka spruce, Japanese larch, Douglas fir and Western hemlock.

There were heavy losses of seedlings on all plots treated with linuron at 1 lb. or more, Douglas fir being less affected than other species. On plots sprayed with linuron at ½ lb., losses were appreciable though not always statistically significant.

Plots sprayed fourteen days after sowing sustained somewhat fewer losses than those sprayed when a pre-emergence application of vaporising oil would be made.

Linuron at ½ and 1 lb. per acre controlled weeds less effectively than a single pre-emergence spray of vaporising oil, but the higher rates were as good or better. No effect on weed crops, due to date of application, was observed.

'P.C.A.'

This herbicide has been found of value as a pre-emergence spray for crops such as sugar beet. In its first year's test as a pre-emergence spray on conifer seedbeds in Britain, P.C.A. was applied at 1, 2, 3 and 4 lbs. in 40 gallons of water per acre. Sprays were applied 14 days after sowing, and at the time of the standard pre-emergence spray of vaporising oil. Plots were sown with Sitka spruce, Japanese larch, Douglas fir and Western hemlock.

The number of Sitka spruce and Japanese larch seedlings was significantly reduced on plots sprayed with P.C.A. at 3 and 4 lbs. per acre at both dates of spraying. The number of seedlings of the two other species was unaffected by treatment.

At the end of the growing season, the mean height of Western hemlock was not affected significantly by treatment, though plants on the plots sprayed at 4 lbs. were appreciably smaller. The height of Japanese larch and Sitka spruce seedlings was reduced by between a quarter and a half by P.C.A. at 3 or 4 lbs. and by about 10% by 2 lbs., though this last difference was not statistically significant. The date of application had no effect on the response of any of these last-mentioned species. However, Douglas fir seedlings were significantly smaller on plots sprayed with P.C.A. at 4 lbs. per acre 14 days after spraying, but were not affected by the same rate applied a few days later, at the time of normal pre-emergence spraying.

With P.C.A., the weeding times varied inversely with rate. However, in contrast to the results with paraquat, plots sprayed with P.C.A. two weeks after sowing took less time to weed than those sprayed a week later, supporting the observation already made that weeds are most susceptible to P.C.A. in the cotyledon stage, and become more resistant as they develop.

Post-emergence Control of Weeds in Seedbeds

Preliminary crop sensitivity tests were made on three herbicides for control of weeds in seedbeds after emergence of the young conifer crop, using Japanese larch, Douglas fir, Sitka spruce and Western hemlock as the test species.

The herbicides were first applied either three or six weeks after all test species had commenced to germinate on all plots.

Solan. This was applied at 1½, 3, 4½ and 6 lbs. sprayed in 40 gallons of water per acre and repeated at intervals of 3 to 4 weeks. Japanese larch and Western hemlock were susceptible to the spray at the higher rates and sustained severe damage. Sitka spruce and Douglas fir, though much more resistant, were nevertheless harmed by the higher rates of the spray, especially on plots treated three weeks after emergence rather than six weeks.

'P.C.A.' This was applied at the same rates as in its test as a pre-emergence spray, i.e. 1, 2, 3 and 4 lbs. per acre in 40 gallons per acre. The spray was repeated at intervals of 3 to 4 weeks. All four species were severely checked by the heaviest rate of spray, Japanese larch and Sitka spruce being more susceptible than Douglas fir and Western hemlock.

Neburon. This residual herbicide was applied twice in the season at 1, 2, 3 and 4 lbs. per acre in 40 gallons of water per acre. Sprays applied three weeks after sowing reduced yields and growth of Japanese larch, Sitka spruce and Western hemlock, but Douglas fir was unaffected. Sprays six weeks after germination had little effect on any species except at the highest rate of application when yields were decreased.

Control of Weeds in Transplant Lines

Long-term Effects of Simazine

At Kennington and Wareham in 1962, simazine was sprayed at 1, 2, 4 and 8 lbs. active ingredient in 40 gallons of water per acre, to a range of species. The site of these experiments has been earmarked for annual retreatment with simazine at the same rates as in 1962, thereby establishing plots where the build-up of simazine residues can be studied.

In 1963, the plots carried transplants of Sitka spruce, Corsican pine, Scots pine, European larch (all at both nurseries), and Douglas fir, Western red cedar and beech (at Kennington only) and Lawson cypress, birch and Western hemlock (at Wareham only).

At Kennington, European larch was the only species to show any ill-effects due to simazine. At Wareham, Western hemlock on plots sprayed at 8 lbs. were somewhat checked in growth. This experiment was delayed by the severe winter, and transplanting was unavoidably delayed until some species had flushed. As a result there was quite substantial browning of foliage on all plots, including controls. This was attributed to late work, but may have masked effects due to simazine.

J. R. Aldhous

STOCKTAKING METHODS

For the past two years, four Conservancy nurseries in Scotland have tried out a new method of stocktaking, worked out in collaboration with the Statistics Section. The method of stocktaking in use since the 1920's is laborious, liable to error, and cannot easily be checked. The new method involves counting smaller samples, which reduced inaccuracies and enables checks to be made easily. It uses preliminary counts to estimate the sampling percentage required. This new method has been found to be successful, and is to be adopted experimentally by all nurseries in Britain this coming year.

J. Atterson

SILVICULTURAL INVESTIGATIONS

By M. V. EDWARDS, R. M. G. SEMPLE, W. O. BINNS AND SILVICULTURE STAFF

AFFORESTATION OF DIFFICULT SITES

The Northern Isles of Scotland

Advisory work to crofters and others continues. A detailed description of the first ten years of the Forestry Commission trial plantations in Shetland has been prepared for publication. These plantations have been inspected annually (for several seasons twice yearly) by the Research Head Forester who assisted in their planting. Thus the climatic effects of successive years can be compared and related to the climatological data published by the Meteorological Office. The success of these plantations up to date has been more dependent on winter conditions than on the climate of the growing season. It is probable that the latter will have increasing influence as the trees by mutual shelter overcome the main adverse feature of the climate, viz. blast. It is also of interest that the tatter of flags exposed near these plantations has been correlated more closely with the duration of winds above 34 knots than with total windrun, i.e. the flags are apparently most responsive to the type of winds which damage the trees.

S. A. Neustein

'Hard Heaths'—Factors Influencing Rates of Growth

This name is used to designate the soils developed on glacial drift soils, mainly of Old Red Sandstone derivation, in the North-east of Scotland, in which a severely indurated layer is developed in the lower part of the B horizon. The layer is usually within two feet of the surface and may be several feet thick. Such soils are general in the Forests of the Black Isle, Teindland and Speymouth, where they support rather slow-growing crops of Scots and Lodgepole pines, characterised by irregular patches of extremely poor growth. Although the general level of productivity of these soils can be raised (at least initially) by increasing intensity of cultivation (see page 158), the patches of poorer growth still become evident within ten years of planting. The problem has been investigated by Research Branch staff at Teindland and by Mr. J. G. Hamilton, an Edinburgh University Forestry student, at Millbuie, Black Isle Forest.

Tree growth does not appear to be associated with nutrient supply, as assessed by foliar analysis, nor with the depth to the indurated layer. It is related inversely to soil moisture and the height of the water table, and is concluded to be a function of root activity as controlled by periodic water-logging. This in turn is not related to surface topography nor to the physical composition (texture) of the soil in good and poor patches, nor to their hardness (resistance to mechanical penetration); it is most probably due to variations in total pore-space or pore-size frequency distribution.

D. W. Henman

Industrial Sites

The proposal to site a new town at Livingston (West & Mid Lothian) has turned attention on to means of improving the scenic and amenity values of the numerous very large shale bings in the area. From observation it appears that stable weathered surfaces are not inherently infertile, as several shrub and tree species have colonised the lower slopes naturally. There are, however, possible difficulties in tree establishment on the raw material which will be exposed when extensive re-shaping of the conical bings has been completed. Advice has been given to the public authorities concerned on the most likely species and establishment methods.

Observations have continued on the growth of trees on pulverised-fuel ash, the residue from modern coal-fired power stations. The alkaline reaction of the ash and the presence of toxic elements, together with the occurrence of cement-like layers in ash that has been deposited as a wet slurry into lagoons, appear to limit the possibilities of forestry on this material. But the natural regeneration and continued growth of birch on an ash deposit at a power station in Shropshire, and the widespread occurrence of birch and willow on a site at Newcastle-upon-Tyne, suggest that the more tolerant hardwood species might do well enough to improve the amenity of power stations and to provide shelter for neighbouring farm crops. At Connah's Quay, Flintshire, a small species trial has shown that alder, and possibly *Robinia pseudacacia* are two other trees that merit further use on this type of material.

A small species trial planted by the North Thames Gas Board on a deposit of clinker and miscellaneous chemical waste is being kept under observation. Various noxious materials associated with the manufacture of household gas, fertilisers and other related products have been tipped, and it is probable that parts of the site will not support tree growth. But the trial affords an opportunity of studying tree establishment on steep slopes liable to erosion and, since it is located in an area of considerable industrial activity, at Beckton, West Ham, the tolerance of a number of tree species to atmospheric pollution can be observed.

S. A. NEUSTEIN
J. JOBLING

Plantations at High Elevations in Wales

Detailed surveys of all the Welsh sites have been completed during the year. One further site has been established just below the summit of Pen Pumlumon (Plynllimon) Arwystli, Hafren Forest, Montgomeryshire, at an elevation of 2,400 feet. This is the highest plot yet planted and brings the total in Wales to eight. Sitka spruce, Lodgepole pine and *Abies procera* have again been the species used in this latest plot.

A. I. FRASER

AMELIORATION OF FOREST SITES

Nutrition

Older Crops: Pole-Stage Manuring

The results of the experiments laid down in the South in 1958 and 1959 (*Rep. For. Res., For. Comm.* 1962) are presently being analysed statistically;

it is clear, however, that the responses are small. In contrast, 76-year-old Scots pine in Alltcailleach Forest, Aberdeenshire, has shown a marked increase in girth increment after NP applications (Keay 1964); this confirms recent similar reports from Central Europe and Scandinavia. It seems that stands of older trees may be more responsive to fertilisers, particularly nitrogenous ones, than trees in the early pole-stage, and this encouraging result from Scotland is to be followed up elsewhere.

Potassium Deficiencies on Peat

The pre-eminent place of phosphorus as the nutrient most commonly deficient in British forests, and the relative ineffectiveness of other nutrients in improving tree growth, has tended to make foresters forget that there are twelve other elements supplied by the soil and known to be essential for trees. Nitrogen and potassium are the most important of these but (except in forest nurseries) potassium has very rarely limited tree growth on mineral soils under normal forest conditions in Britain, though deficiencies have been reported from other countries.

Since about 1956 it has been clear that trees on deep acid peat can, like agricultural crops, suffer from severe potassium deficiency; the first responses were obtained in Scotland and were later confirmed in Wales (*Rep. For. Res., For. Comm.*, 1959 & 1962). The visual symptoms of mild potassium deficiency in Sitka spruce on deep peat are characteristic and striking: the current needles are green while older needles show an increasing yellowness. In severe cases the current needles are yellow as well, and may fall when only 1½ years old. These symptoms seemed widespread in North Wales, so at the request of the Conservator the foliage of sample trees representing over 1,000 acres of deep peat was analysed last winter.

The suspected potassium deficiency was confirmed in about 950 acres, 300 acres of which were also phosphorus deficient; a few areas seemed to be deficient in nitrogen, not potassium, a finding which was confirmed in the field. In the worst areas—Tarenig, Hafren and Dyfnant Forests—the potassium concentrations in the needles were very low, 0·1–0·2%, compared with a normal 0·6–1·0%.

The Conservator has been advised to use fertilisers to supply 84 lb. K per acre, supplemented where necessary by P at 22 or 44 lb. per acre. The intention is to treat all the ground in 1964 and 1965.

REFERENCE

KEAY, J., 1964. Nutrient deficiencies in conifers. *Scottish Forestry* 18, 22–29.

W. O. BINNS

Upland Heaths

Three experiments designed to estimate the maximum response of slow-growing pure Sitka spruce to an optimum application of fertiliser have been established at Wykeham, Allerston Forest, Yorks. In addition a stagnating Japanese larch crop at the Dalby section of Allerston was similarly treated. This project attempts to isolate the moisture factor. No visible tree response to the fertiliser has appeared after one season. (Foliar analysis of the Sitka spruce before treatment suggested that only nitrogen was really deficient).

S. A. NEUSTEIN

Deep Peats

The most important problem in forest nutrition in the not-too-distant future will be the nutrition of trees growing on deep, acid peat, where nutrient supplies are adequate to establish a plantation (with added phosphate, of course), but are very marginal for continued growth. Most deep, acid peats in Britain have a high total nitrogen content (1·25–2·5% oven-dry peat) which is fortunate as nitrogen is an expensive, short-lived nutrient when applied as an inorganic fertiliser. The problem with the nitrogen in the peat will be to make it available to the trees. Phosphate is usually very low in these peats, but can be and is increased by any of the common phosphate fertilisers, one application lasting anything up to twelve years. Potash is usually also very low, and although it can be added as an inorganic fertiliser, it is doubtful if it will give as prolonged a response as can be obtained with phosphate. The main objective, therefore, of nutrient research in the next few years will be to determine the most economical method of application and type of potash fertilisers (and repeat dressings of phosphate). It is possible that other nutrients will also become deficient on such sites and a watch will be kept for this. Some sites have already been chosen for these proposed experiments at Shin, Mabie and Arecleoch Forests.

Use of Lime

Two groups of manuring experiments which have been reviewed during the past year are concerned with liming and the use of triple superphosphate in forests, the latter bringing the results given by Edwards in 1959 (*Rep. For. Res., For. Comm.*) up-to-date. The group of liming experiments was begun in 1952, and rates of ground limestone of up to 4 tons per acre were applied at planting to Scots pine, Japanese larch and Sitka spruce on four sites, the sites being Allerston (Broxa), Teindland, Watten (Caithness) and Glentrool. Phosphate and potash were applied as a basal dressing to all plants at the same time. After ten years the only significant effect of liming was a definite increase in the height of Japanese larch at Allerston (see Table 2).

Table 2

EFFECT OF LIME ON LARCH AT ALLERSTON

Lime applied (tons per acre)	0	¼	1	4
Height of Japanese larch (in ft. after 10 years)	7·8	8·2	9·3	10·5

The other experiments showed no effect of liming throughout the ten years, so that the only conclusion one can draw is that lime is rarely limiting on acid heaths and peat for the species tested, and at this stage of their growth.

Use of Triple Superphosphate

The group of experiments comparing triple superphosphate with ground mineral phosphate has been continued to see if the conclusions drawn by Edwards in 1959 (*Rep. For. Res., For. Comm.*), on results obtained after three growing seasons, were still valid after a further three growing seasons. The main conclusion drawn after the first three growing seasons was that ½ oz. of triple superphosphate produces the same growth on conifers planted on acid heaths and peats as 1½ ozs. of ground mineral phosphate, even though the latter contains twice the quantity of total phosphate as the former. This result may have been due to either or both of the following reasons: (1) the phosphate in ground mineral phosphate is less soluble and less readily available than that in triple superphosphate, and (2) the smaller quantity of phosphate applied as triple superphosphate was sufficient for three years' growth of conifers on the sites tested. After a further three growing seasons, however, the position described by Edwards remains the same, as there are still no significant height differences between trees treated with the two types of phosphate. Nevertheless, in almost all the experiments the needle phosphate concentration is greater in trees which received ground mineral phosphate, which suggests that eventually the trees treated with ground mineral phosphate will prove to be superior.

Unfortunately, the design of these experiments does not permit the form of phosphate and the rate of total phosphate to be distinguished. It will not be possible to continue these experiments further because of the small plot size, but in the long term it seems probable that it is the total amount of phosphate in a fertiliser which determines the growth response. If this is the case, and as the cost of one unit of phosphate bought as triple superphosphate is twice that bought as ground mineral phosphate, the latter fertiliser appears the obvious one to use on acid heaths and peats. In some places, where transport is difficult, triple superphosphate may be the most economical phosphate fertiliser to use, as only two-thirds the quantity normally applied as ground mineral phosphate need be applied as triple superphosphate, i.e. 1 oz. triple superphosphate is equivalent in total phosphate content to 1½ ozs. ground mineral phosphate.

J. ATTERSON

Cultivation of Heathland, Teindland Forest

In view of the early benefits shown by deep (13 ins.) complete ploughing compared with standard spaced tine ploughing on the hard heath soils of Teindland Forest (see page 158) a further long-term experiment has been established at Teindland to compare these two cultivation methods. This will also provide a more precise test of the compartment-sized comparison being carried out on neighbouring ground by East Scotland Conservancy, where the principal object is to compare the costs of the two methods. In addition, the possibility of being able to grow higher-yielding species on this ground, after intensive preparation, is being followed up by the inclusion of Sitka spruce and Western hemlock.

D. W. HENMAN

Drainage

Drainage Demonstration, Kielder Forest

In co-operation with the staff of North-east (England) Conservancy an area covering four compartments is being maintained at Kielder Forest for special observations on the development of the drainage system. The area was ploughed and drained in accordance with the best available knowledge and the gradients, depths and rates of erosion and silting in drains will be periodically recorded.

Drainage of Deep Peat—Flanders Moss, Loch Ard Forest

Plots have been laid out in four replicated blocks for the large draining experiment which will be established on Flanders Moss during the summer of 1964. As a considerable sinking of the surface of the bog is anticipated, an iron post has been driven through about twenty feet of peat and screwed into the underlying clay to serve as a datum for future levelling surveys.

Drainage of Mineral Soils by 'Rigging'

The applicability to forest drainage of the old-fashioned agricultural system of 'riggs' and 'furrs' (ridges and furrows) is being examined in forests in Yorkshire. The method involves forming the ground into undulations which measure 20–25 feet from crest to crest and 2–3 feet from crest of 'rigg' to bottom of 'furr', these are aligned in a general up-and-down-hill direction. Trees are notch-planted over this formation at normal spacing, avoiding the bottom of the furrs. Possible advantages of the method are that a permanent drainage system is imposed on the ground which is more efficient in shedding surface water and which does not involve deep, near-contour cross-drains which restrict extraction and require regular maintenance. After a trial at Bickley, Allerston Forest, which showed that the riggs can be formed with an angle-dozer, the method has been incorporated in a large-plot experiment at Rosedale, also in Allerston Forest, in comparison with normal spaced-furrow ploughing and with deep complete ploughing, all three methods being further compared with and without deep near-contour drains.

D. W. Henman

Drainage of Heavy Clays

The establishment of the experiment at Orlestone Forest in Kent, which has been designed to examine the effect of different drain spacings and drain depths, and their interaction, was completed during the year.

The Halwill Forest (Devon) experiment on drain spacing, with and without mole ploughing, is continuing to yield interesting information, and the measurements of flow and borehole water levels are being continued by the Soils Section.

One additional small experiment was laid down at Halwill to study the effect of complete ploughing with drainage. To date all ploughing in the area has been single furrow.

New Equipment

A new County Super 4 tractor was acquired during the year, and the Research Branch hydraulic excavator was mounted on it. This type of vehicle, with drive transmitted through four large equal-sized wheels, was considered to be the most adaptable for forest conditions. The wheels enable stumpy ground to be negotiated more easily than with tracks, and the possibility of fitting very large tyres means that the machine may also be usable on very soft ground.

The machine is primarily intended as a Research Branch tool for digging drains required in experiments, but development work on the tractor and digger will continue as required. Useful experience is being gained on the rates of work, costs, and handling characteristics on a wide range of sites.

A. I. Fraser

NATURAL REGENERATION

Seed Trapping—Douglas Fir

The seed trapping experiment in Douglas fir, being run jointly with the Entomologist, has been extended to a total of six sites. These range from Culloden in North Scotland to the New Forest in South England, and from Brecon in South-west England to Thetford Forest in East Anglia. The experiment is a long term one, in that the objects are to find the periodicity of good seed years on a geographical basis, and at the same time measure the quality of the seed. The period September 1963 to March 1964 was very poor from the point of view of seed production, except at Thornthwaite in Cumberland, where it was estimated that a total of 26,800 viable seed fell per acre. This represents 15·4% of the total seed fall; the remainder being either empty or infested with the Douglas fir seed wasp, *Megastigmus spermatrophus*. (See Plates).

A. I. FRASER

ARTIFICIAL REGENERATION

Spruce in the Borders: Size of Felling Area

The preliminary results of the experiment at the Forest of Ae (Dumfriesshire) comparing four sizes of felling area in relation to the amount of consequent windthrow is summarised under the title *Windthrow on the Margins of Felling Areas* in Part III of this report. The main results up to date are the lesser amount of damage per acre felled in the larger clearings and the unexpected slow rate of re-invasion of vegetation. In view of the importance of this project it is proposed to repeat the experiment on broadly similar lines, in order to test what appear to be fairly definite indications from this preliminary, somewhat under-replicated, experiment. (See Plates).

Manuring: Second Rotation Crops

In 1963 six experiments were established with the object of testing two rates of nitrogen (as 'Nitrochalk'), applied at time of planting, on a variety of species, as an initial 'boost' in growth, to get them quickly above colonising weeds.

In none of the experiments was there a visible response to the nitrogen at the end of the first growing season. After some root examinations this negative result could be clearly attributed to the fact that the replanted trees do not begin to grow, under the peaty conditions obtaining, until a new feeding root system has been established. This same phenomenon was noted by Dr. E. V. Laing as long ago as 1923 at Inverliever Forest in Argyll. Further trials of nitrogen manuring in years subsequent to planting are being pursued.

Direct Sowing of Sitka Spruce

The clear felling experiment at the Forest of Ae has suggested that the colonisation by grasses of clear-felled, fully stocked spruce areas is much slower than expected. Three years of reasonably weed-free conditions are likely. Natural regeneration of Sitka spruce is surprisingly abundant, considering the scarcity of cone-bearing trees, and therefore suggests a high germination rate under the prevailing conditions. Previous direct sowing experiments of Sitka spruce in afforestation experiments have often been bedevilled by early suppression by grasses or later check by heather, *Calluna vulgaris*—both of which hazards may be avoidable in the second rotation. This year several short-term trials of direct sowing of Sitka spruce under typical regeneration conditions are being established, in order to observe closely the germination and subsequent success of a known number of seeds.

S. A. NEUSTEIN

Underplanting of Japanese Larch

The underplanting experiment beneath Japanese larch at Drumtochty Forest mentioned in the previous two reports has been satisfactorily established. The first season's survival was generally good in all species without any significant variation due to differences in overhead shade.

In this experiment simple measurements of light intensity have been made for the first time and the results have been sufficiently promising to justify further use of this technique in other underplanting experiments.

The third in the series of underplanting experiments has been established at Radnor Forest in mid-Wales. Felling was delayed last year by the severe winter, and so planting was postponed for a year.

Light readings in the existing experiment at Coed Morgannwg in South Wales show a useful correlation with the number of stems per acre left.

The light intensities measured in the centre of the plot as a percentage of the light in the open, under different densities of larch were:—

30 stems per acre	86·8%	±	3%
60 stems per acre	77·3%	±	4%
120 stems per acre	66·8%	±	2%
200 stems per acre	53·6%	±	2%

S. A. NEUSTEIN
A. I. FRASER

Regeneration of Scots Pine at Thetford Chase

The experiment at Thetford Chase in East Anglia, laid down two years ago, to investigate the establishment of second rotation crops under pine cover, has been extended.

At Thetford the soils vary from shallow and alkaline, to deep and acid extremes. The fungus *Fomes annosus* is severely damaging some stands and is the major consideration when regenerating. The climate is difficult, in that the locality is very susceptible to spring frosts, as well as having a low rainfall and a liability to spring droughts. All these factors must be taken into account when regenerating and choosing the species for the second rotation. Corsican pine is to date the obvious choice for replanting unsatisfactory Scots pine crops, but it is possible that other species would be more tolerant of the alkaline soils and more resistant to *Fomes annosus*. In order to obviate some of the difficulties of the climate it has been decided to establish plots of tried species under a light pine cover. Eighteen species were planted this year, on sites on the three major soil types, in 1/10th acre plots, under a density of 200 stems of Scots pine per acre. The species used were:—Scots pine, Douglas fir, Western hemlock, Western red cedar, Lawson cypress, Leyland cypress, Hybrid larch, Serbian spruce (*Pinea omorica*), *Cedrus atlantica*, *Abies alba*, *Abies amabilis*, *Abies cephalonica*, *Abies grandis*, *Abies lowiana*, beech, Red oak and *Nothofagus obliqua*.

In order to assess the effect of the pine cover, measurements of the minimum temperature were made throughout the winter, and will be continued through the spring. To date the results have shown that, when below freezing, the temperature under the tree cover is persistently warmer than in the open, at heights of 6 inches, 12 inches and 24 inches. The difference in temperature depends on the severity of the frost, becoming greater as the outside temperature drops. Fig. 1 shows the outside temperature plotted against the difference in temperature in degrees Fahrenheit: it can be seen that at freezing (32° F) the difference is nil, but with 20 degrees of frost (12° F) the difference is over 10°F.

A. I. FRASER

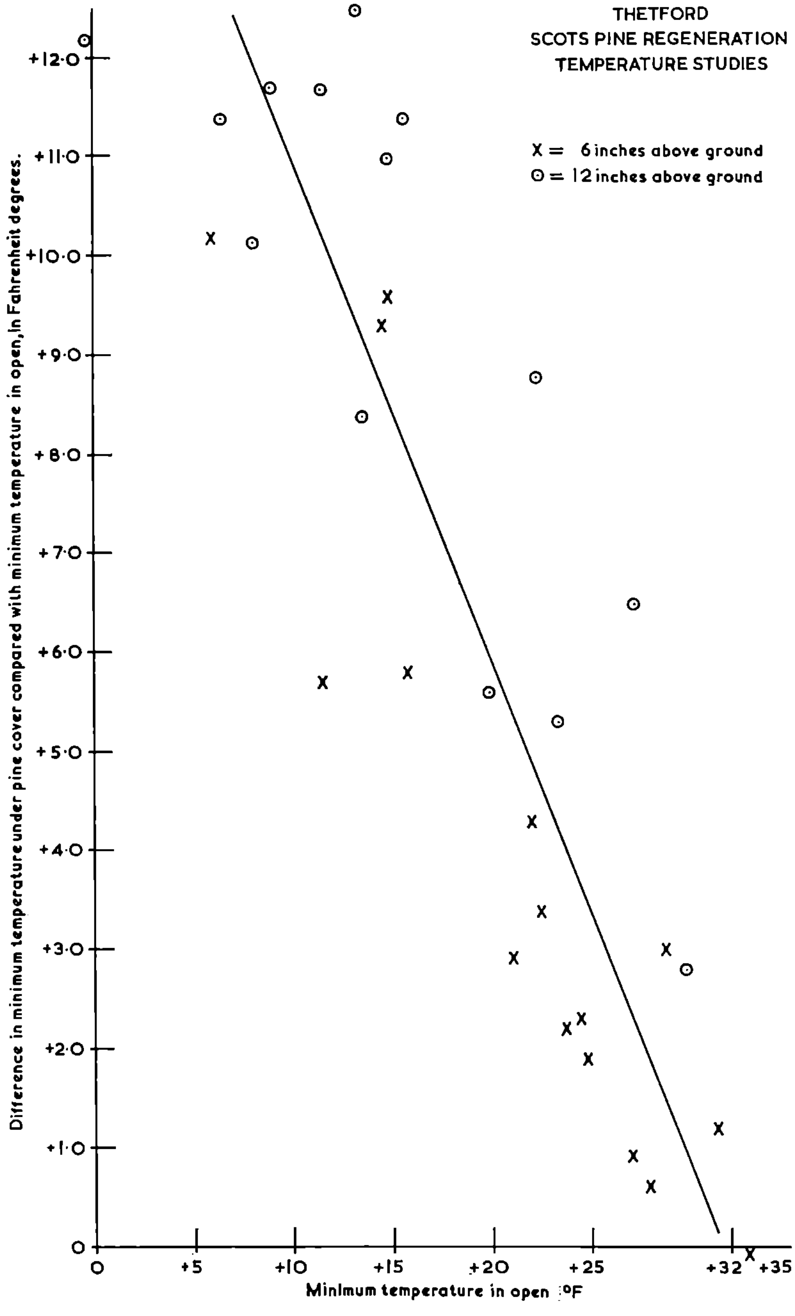

FIGURE 1. Regeneration of Scots Pine at Thetford Chase: Differences in Temperatures. The difference in temperature between points 'outside' and underneath tree cover are here plotted against the 'outside' temperature.

Species Trials

Euaclypts at Kilmun and Crarae, Argyll

The number of forest plots at Kilmun, Benmore Forest, Dunoon, and Crarae near Inveraray, continues to increase and some of the older plots are now of much interest. At Kilmun, where the Forestry Commission has its best collection of Eucalypts, some of the species of this genus planted in the early 1950's are now of considerable size, have good stem form, and have withstood the two severe winters of 1961–62 and 1962–63. The best species to date for height growth and stem form is *Eucalyptus subcrenulata* forest type, (also known as *Eucalyptus vernicosa* sub-sp. *columnaris*) which has reached a mean height of 50 ft. only fifteen years after planting. *Eucalyptus urnigera* is also very promising and has reached a mean height of 40 ft. after only ten growing seasons. A species which promises even better height growth and stem form than the two just mentioned, but which may not be quite as hardy, is *Eucalyptus gigantea*, one individual of which has grown more than 20 ft. in four growing seasons. It is pertinent to mention here that the climate at Kilmun is very mild compared with the rest of Scotland and the success of the Eucalypts at this site is undoubtedly due to this. As growth has been so promising further plantings of the best species of Eucalypts are planned.

J. Atterson

Winter Damage to Southern beeches, Nothofagus species

During the extremely severe winter of 1962/63 extensive injury again occurred to the lower part of the stems of *Nothofagus procera;* the worst cases were in frost hollows and lower valley slopes in Wales and the Forest of Dean. *Nothofagus obliqua* was also injured but less severely; the damage appeared to be more closely associated with exposure than with relative elevation.

In both species there were two main forms of visible injury. The most obvious were open splits and wide stem wounds; these were most common in *N. procera*. The less conspicuous damage took the form of flattened, slightly darker patches of bark, covering dead or damaged cambium. Either type of injury may lead to dieback of the upper parts of the tree; this is frequently accompanied by the formation of many new shoots at the base. (See Plate).

Internal examination of annual rings indicates that winter cold, and not spring-frosts, is the main cause of injury; but the pattern of severity of damage in different parts of the country is not easy to interpret. There is a suggestion, however, in the case of *N. procera* that sites with a wide range in temperature may be more damaging than those with equally low minima, but less high day temperatures. As an example, damage in East Anglia is less than one would expect. Observations continue but it is clear that it would be unwise at present to recommend the large scale planting of either of these species.

M. Nimmo

PROVENANCE

Scots Pine

The results of some of the older experiments with Scots pine provenances are reported in Part III in the paper by R. Lines and A. F. Mitchell on page 172.

The experiment at Glentrool planted in 1949 was assessed for needle browning in May 1963, after the severe winter of 1962/63. There was little snow to protect the trees at Glentrool. The West Coast provenances, Loch Shieldaig and Rhunoa, Loch Maree, both in Wester Ross, were highly significantly less affected than the inland Speyside provenance from Rothiemurchus, Inverness-shire, despite the fact that they were appreciably taller than the latter.

Pinus nigra: Corsican Pine and Related Pines

Seed from thirty areas covering much of the range of the species and including stands on calcareous soils was sown at Wareham Forest in Dorset. The earlier experiments, containing some interesting provenances, including Turkey and Koekelare (Belgium), showed, after five years, some clear differences in the form of trees, but needle characteristics differed within the plots. As noted in earlier reports, needle characteristics can be misleading in young material, and assessments for these differences in needle characters will be delayed until they have outgrown the juvenile form. In the experiment planted at Haslingden Forest in the Pennines in 1962, survival rates in the autumn ranged from 86 to 100%, but heavy losses were sustained during the severe winter, some provenances suffering losses of 40 to 50%, while in the Austrian provenance deaths amounted to only 3%.

Lodgepole Pine

The experiment on an upland heath at Wykeham (Allerston) which contains nine Sample Plots was thinned for the third time. Total volume production at 25 years ranged from 2,860 cubic feet per acre for the coastal provenance from the Olympic Peninsula, Washington, to 2,080 cubic feet per acre for two seed lots from Prince George in the northern interior of British Columbia. An assessment of internodal branching carried out in this experiment showed that additional whorls of branches were particularly common in inland provenances and in those from the Skeena River; whereas they were uncommon in Washington and British Columbian coastal provenances and quite rare in those from the coast of Oregon. The only inland provenance in which they were uncommon was a slow-growing one from Oregon. It is clear that there is no correlation between growth vigour and the production of internodal branches in this experiment. See Plates 8 and 9 for illustrations of Olympic Peninsula and Prince George stands.

The four-year-old experiment at Glentrool, not far from the Scots pine experiment noted above, also suffered from the severe winter of 1962/63. A Vancouver Island provenance from Ladysmith was blasted much more severely than any other, though one from Keyport in the Puget Sound was also quite badly affected. The remaining provenances did not differ significantly in the amount of blasting; the inland ones, being one third less tall than the coastal ones, may have been sheltered to some extent by the latter.

At Taliesin Forest in mid-Wales, in severe exposure near 2,000 feet, sharp differences were apparent between southern coastal and northern origins. The three from the Oregon coast remained a good colour through the winter and retained two to three years' needles. Their dense crowns and vigorous growth render them liable to be blown over. The inland and coastal British Columbian origins were severely discoloured by blast and retain only one year's needles, but being smaller and sparser, remained upright.

Seed lots from Anahim Lake and Bella Coola showed some anomalies, so a new batch of seed was sown together with seed from several origins, both inland and coastal, of better known characteristics, and these have been planted on three sites: Clocaenog in Denbighshire, New Forest, and a very difficult sand-dune site at Newborough (Anglesey). Parallel experiments in Scotland are at Achnashellach; Forest of Deer, and Elibank.

Douglas Fir

The experiment planted in 1943 at Glentress Forest has been thinned for the first time. The total basal area (main crop and thinnings) was very similar for four British Columbian coastal origins, while two provenances, Prince George and Shuswap Lake, from the interior, had one quarter less basal area production. This may well be due to rather heavy *Rhabdocline* (leaf cast fungus) attack on the interior provenances. Only a proportion of the trees were affected, and as these poorer trees are removed in thinning, the gap between the provenances can be expected to narrow. No damage resulted from the winter of 1962/63.

At Shouldham, Lynn Forest, Norfolk, the experiment planted in 1954, which compares the seed zones recognised by the firm of Manning, suffered considerable damage from the winter frosts of 1963. Assessment of height of the top third of the trees of each origin showed that Castle Rock was slightly ahead of Elma, Hoquiam and Enumclaw (high elevation). This is interesting since Castle Rock, on the north side of the Columbia River, 68 miles inland, is near the area where David Douglas collected the original and highly successful seed in 1827. Elma and Hoquiam are both 60 miles north of this on the Chehalis River. The best origins all seem to be from the relatively small part of Washington between the southern extremities of Puget Sound and the Columbia River.

In the three Scottish experiments with these origins, hardly any damage resulted from the winter of 1962/63. This is surprising, in view of the fairly severe damage at Glentress caused by the less extreme winter of 1954/55. The provenances which have grown fastest in the south have also done well further north, though the differences between the best and worst provenances were not significant. A provenance from Shuswap Lake, interior of British Columbia, has also made a good start and was just as tall as the better Washington provenances. However, attack by *Rhabdocline* has commenced, so that its growth may decline in the same way as that of the older plants at Glentress.

In a group of younger experiments, planted at Thornthwaite, Castle O'er, and Elibank in 1959, and the following year at the Forest of Dean, some provenances were severely damaged by the winter of 1962/63. The provenances are from eight Scottish Seed Stands and from five areas in North West America. The worst affected experiment was Thornthwaite, which is on a fairly steep north-facing slope, and where some provenances suffered losses of up to 50%.

In general, the Scottish provenances tended to be less winter-hardy than those directly imported from America, with the notable exception of Culloden, which suffered little damage despite being one of the tallest provenances. The damage at the Forest of Dean was on a much reduced scale compared to that in the Scottish experiments.

Sitka Spruce

In 1956 and 1957 Sitka spruce seed of Alaskan origin (I.N. 55/3 Cordova and 56(7987) Juneau) was sown in Conservancy nurseries in Scotland and England. At Research Branch request, trial areas of at least one acre were planted adjacent to, and on sites where it could be compared with, Sitka spruce of the standard Queen Charlotte Islands origin.

The trials were planted in 1959 and 1960 on 100 sites in 45 forests, mainly in North, West and South-west Scotland, and in North-east and North-west England. The variation in sites ranged from high-lying, exposed moorland to more fertile low-lying areas and covered most of the ground types where Sitka spruce is likely to be planted. The Research Branch have collated the lists of sites and inspected nearly all of them.

Out of the 100 trials, only 25 were considered suitable for retention. Many of the Alaskan spruce plots were laid down without Queen Charlotte Islands comparisons, or on sites where the conditions were too variable. The 25 comparable trials, however, gave a fairly good cover of the country from Borgie in Sutherland to as far south as Bowland in Lancashire.

Although no detailed assessments have been carried out, the most interesting observation to date was the effect of the severely cold weather during the winter of 1962–63 in South-west Scotland and North-west England. Here the Queen Charlotte Islands spruce were often so severely blasted that 25 to 30% were killed-back almost to their base, whereas the Alaskan plants suffered comparatively little damage. In North Scotland it was noted by some observers that the Alaskan spruce often flushed earlier and were consequently more liable to damage by late spring frosts than the other origin. Where comparisons can be made, the Queen Charlotte Islands trees were usually taller than the Alaskan plants. The 25 plots will be assessed for height and survival at the end of six years' growth.

The trials planted in 1960 of provenances ranging from Alaska to Oregon, are establishing well with very few losses, except on the most severely exposed sites. In Wales the arctic spell in 1963 had no damaging effect except in a frost-hollow site, probably because elsewhere there were no hard frosts after the early March thaw. At the most severe site in Wales, two Alaskan provenances showed poor survival and growth while two others were reasonably promising, but no better than one southern origin (Jewell, Oregon). At all other Welsh sites the Alaskan and mainland British Columbian origins were much inferior to Queen Charlotte Island, Vancouver Island, Washington and Oregon provenances. In all these sites Sooke, from the southern tip of Vancouver Island, was tallest or second tallest, while Hoquiam, Jewell and North Bend were, in varying order, among the tallest. In Scotland and northern England the pattern of growth was similar to that in Wales, with the main difference that the most southerly origin—from North Bend, Oregon, was equally as tall as the Sooke provenance and the hardiness of the Alaskan provenances was more clearly demonstrated. An additional provenance from Seward on the Kenai Peninsula of Alaska grew appreciably faster than the other Alaskan ones at three sites.

Western Hemlock

The experiments established under light high shade were largely untroubled by the severe winter and, particularly in the New Forest, are growing with great vigour, one plant adding four feet to its height. The Scottish experiments were all planted on bare hillsides and many suffered badly as a result. In particular, the experiment at Glentrool has had to be written off and that at Gisburn required heavy beating up. However, the experiments on particularly exposed sites at Laurieston and Glen Errochty suffered little damage due to a protecting layer of snow. At this early stage there is some indication that the southern coastal origins are the most vigorous, but this is not as yet consistent.

Other Species

Fourteen lots of seed of the Californian redwood, *Sequoia sempervirens*, representing its whole natural range, were received from California and sown in pans to give trials parallel to those being planted in the U.S.A. Both in the U.S.A. and here several seed-lots have produced one or two giant seedlings three or four times the size of the remainder.

A small trial of progenies of selected trees of *Nothofagus obliqua* from the Bedgebury Forest Plots (Kent), and from Tortworth (Glos.) was established in the New Forest.

R. LINES
A. F. MITCHELL

WEED CONTROL IN THE FOREST

During the year work in the South was concentrated on further tests of two herbicides, paraquat and 2,6-dichlorothiobenzamide. Preliminary trials were also made with 'Tordon' and with equipment developed by Messrs. Shell Chemicals for application of invert emulsions (the 'Stull' bi-fluid system). Field trials testing 2, 4, 5-T in a wide range of conditions were also reviewed, some of the less successful being closed, and the remainder being kept under observation. In the North, small preliminary trials of paraquat and 2,6-dichlorothiobenzamide were conducted.

Paraquat

Paraquat was tested on sites at Gaywood, Lynn Forest, Norfolk, planted with Corsican pine and with a grass flora dominated by *Arrhenatherum elatius* and *Dactylis glomerata*, and at Bere Forest in Hampshire, planted with Norway spruce and with a very wide range of broadleaved and grass weeds.

Paraquat was applied either in late-May/early-June, late-June/early-July or late-July/early-August; certain plots received a second dose of paraquat three months after the first. Treatment was by spray in 40 gallons of water per acre. Paraquat was applied at ½, 1, 1½ and 2 lbs. active ingredient per acre. A hooded sprayer was used to protect the young crop.

At both sites, spraying in late-June and late-July was time-consuming because of the difficulty of getting the spray hood down around the young trees once the grasses and broad-leaf weeds had grown up.

Paraquat applied during the summer at rates between 1 and 2 lbs. per acre gave good control of top growth, but there was extensive regrowth within two months, especially on the plots sprayed in May and June. On plots that were sprayed a second time (i.e. in August, September or October), several species including *Arrhenatherum elatius* and *Dactylis glomerata* were killed. On plots sprayed at ½ lb., the control achieved was not as good as on plots sprayed at the higher rate. At Gaywood, the Corsican pine were not affected by any treatment, but at Bere, some Norway spruce were quite badly browned where the hood had failed to protect the young trees.

Paraquat was also sprayed at ½, 1 or 2 lbs. in 40 gallons of water per acre onto Sitka spruce in heather at Clocaenog and Ceiriog forests both in Denbighshire, North Wales. Treatments were applied in late-July, mid-August or early-September, 1963. On each site, heather, *Calluna* was dominant, with a little blaeberry, *Vaccinium myrtillus* and cross-leaved heath, *Erica tetralix*. Most of the foliage of the *Calluna* was browned by the paraquat spray, even when the *Calluna* was in flower. (The cold winter of 1962/63 delayed flowering by 2–3 weeks). Heather was not killed outright—in October there was a small proportion of green foliage on most stems and the stems were still green. Assessments are required twelve months after treatment to show whether the heather so treated could recover. *Erica tetralix* appeared to be resistant to paraquat.

A range of common conifer species were sprayed with paraquat to determine whether they could resist an overall spray of paraquat at any time between June and September. Most species were severely damaged, the worst affected being oak, pines and Douglas fir; larch and sycamore were less severely damaged and Norway and Sitka spruce appeared the most resistant. These last two species were by no means unaffected, but though there was damage to foliage from paraquat at ½ and 1 lb. per acre applied in late-August and September, it did not appear to be severe and might not dismiss the use of overall sprays of paraquat at this rate. Damage using 2 lb. was too severe on all species to be acceptable, even though, at the end of the growing season in which they were treated, the spruces, sycamore and European larch treated after the end of August appeared likely to recover and sustain no permanent injury.

During the year a prototype hooded sprayer, developed by Messrs. Plant Protection, was tried out. The aim was to enable paraquat to be sprayed right up to the base of young trees, the foliage being gathered together and protected by a U-shaped hood.

This worked well on the whole. It was however noticed that if spray fell on bark at the root collar and base of the stem (coming below the bottom of the hood) kill of the bark might result. Species seriously affected in this way included Western hemlock, Lawson cypress, Sitka spruce and *Abies grandis*. Pines and larches appeared not to be affected, though as this was an incidental effect in a trial of equipment, the observation may not be reliable.

Preliminary trials of paraquat in Scotland were encouraging, worthwhile control of grass vegetation being obtained without damage to trees.

2,6-dichlorothiobenzamide ('Shell 5792')

This chemical was also used on sites at Bere and Gaywood, Lynn Forest, near those used for the experiments on paraquat just described. It was formulated as a granule containing 7½% active ingredient and applied at 1, 2, 4 and 8 lbs. active ingredient per acre, in late-May/early-June, late-June/early-July and late-July/early-August. There was only one application to any one plot in the year.

In contrast to the plots treated with paraquat, the effect of this herbicide was very slow in appearing. It took two months before any visible control of the vegetation could be seen and this was effective only on the plots treated at 4 and 8 lbs. per acre. On plots treated at 8 lbs. a few Corsican pine died but Norway spruce did not appear to be affected.

In a small unreplicated trial at Lyndford, Thetford Forest, laid down in 1962, patches treated with 2,6-dichlorothiobenzamide at 8 lbs. per acre remained substantially free from weeds for most of the 1963 growing season. Preliminary trials of the substance in Scotland offered some promise.

'Tordon' (4-amino-3,5,6-trichloropicolinic acid)

'Tordon' was compared with 2,4,5-T in a preliminary trial on oak, ash and hazel coppice standing or cut back. Treatments were applied in late-summer 1963. The first observations indicate little differences in the effects of the two herbicides.

Invert Emulsions

A preliminary trial on bramble, and on ash, birch, hazel and oak coppice was made in November 1963, using invert emulsions (i.e. water-in-oil emulsions instead of oil-in-water) of 2, 4,5-T. In use, there is much less drift of herbicide with invert emulsions than with the conventional formulations. On the other hand the two components of the invert emulsion have to be kept separated until the last possible moment if the spray system is not to get blocked up. The 'Stull bi-fluid' equipment loaned by Messrs. Shell Chemicals performed extremely well. A preliminary assessment of the control achieved with the invert emulsion indicated that it was effective on bramble but ineffective as a basal bark or stump spray.

J. R. ALDHOUS

WIND STABILITY

Records of Windthrow

New cards for returning information on wind damage were introduced during the year, laid out in such a way as to allow quick coding of the results on the card in a form which makes tape punching easy.

A programme for the computer is in course of preparation which will enable rapid and detailed summaries of wind-damage to be done at any time and for any period.

The period under review was relatively free from wind damage, though damage occurred, somewhere, in every month between September 1963 and March 1964. The total area reported damaged was 170 acres. This compares with 940 ac., 1250 ac. and 330 ac. in the three preceding years.

Tree-pulling Investigations

The tree-pulling studies were continued during the year, with most of the effort being put into an investigation of the effect of spacing. Three spacing experiments were sampled, two in Sitka spruce, and one in Norway spruce, and the results proved very interesting. The differences in the form of the root system between the extreme treatments of 3 ft. spacing and 8 ft. spacing, were very marked. The close planted trees showed a marked tendency to root deeply, while the wide spaced trees had shallower roots, which extended much further laterally. The root systems were weighed, and it was found that the root/shoot ratio remained constant irrespective of the form of the crown or root system.

The root systems of trees pulled over previously at Clocaenog Forest in North Wales, on a range of sites, were closely studied in relation to soil types recognised in the current soil survey. The correlation was so good that it has been possible to give each soil type a wind-damage susceptibility rating. This will be taken into account during the preparation of the working plan and can be used in the prescription of drainage and cultivation treatments.

Surveys of Crop Stability

As an extension and practical exercise of the work described in the preceding paragraph, an assessment was made from data collected by the Working Plan field party at Redesdale Forest in Northumberland, during their crop assessment survey, of the susceptibility of each compartment to wind damage. The assessment was based on the rooting characteristics as seen on the surface in combination with soil description, and information on exposure, elevation and crop composition. Records will be made of the damage in these crops over the next few years, to judge the accuracy of the assessment.

A. I. FRASER

Effects of Thinning and Spacing

The effect of an extreme regime of thinning on the form and strength of the roots of Norway spruce was examined in an experiment at Forest of Ae, Dumfriesshire, where 24-year-old trees which had developed under normal plantation competition were compared with others within the same stand which had remained isolated from crown competition since planting. (See *Rep. For. Res. For. Comm.* 1962, pp. 145–56). The trees were pulled over by a hand winch incorporating a dynamometer. As expected, the rootplates of the isolated trees were wider than those of the controls (diameter about half as wide again) but surprisingly the control trees (i.e. normal planting) were found to root more deeply (root-plate about half as deep again). The soil was not a freely-draining one, so it tended to promote surface water-logging and to restrict rooting depth. It is suggested that the greater ratios of crown weight and crown surface to ground surface area beneath the control trees may enable them to remove more soil moisture and thus permit deeper rooting. This is being tested in a neighbouring isolation experiment in Sitka spruce. The resistance offered by isolated trees to being pulled over was greater by half than that by control trees, probably in large measure due to their greater inertia, as their above-ground weight was about double that of the control trees. This is not, of course, a measure of the tree's resistance to being blown over, since it has been shown that the drag offered by a tree in wind is directly dependent on its above-ground weight.

Further work on this subject is being done in the North in spacing experiments at Newcastleton and Kershope Forests.

D. W. HENMAN

Investigations at Sites of Windthrow

Several more experiments comparing various treatments of the marginal trees of windthrown areas (such as topping, ultra-high pruning, etc.) have been established. Since the first of these comparisons were made in 1963, windthrow of any treated crop face has not been sufficient to indicate effective differences between treatments.

A survey of extensive and increasing windthrow at Kershope Forest (Cumberland) dating from 1958 was completed in 1963. The investigation was based on the Conservancy records of windthrow. Forty-nine windthrow sites, varying from 0·1 to 18·5 acres, and totalling 75·9 acres (two-thirds of the total windthrow area) were visited. A standard form itemising all relevant features of site, crop and past treatment was completed and it was hoped that from such a mass of information a characteristic or combination of factors responsible for windthrow might stand out. The study did not provide clear answers to the question of where and why windthrow starts, and why it stops in a particular case, and it suffered from having been confined to the thrown areas without comparisons with surrounding standing areas. Nevertheless several important points emerged, viz:

(a) The upper slopes are most susceptible.

(b) Gales capable of causing damage are frequent and nearby Meteorological Office instruments show that such gales were very frequent in 1961 and 1962. Hence the windthrow increase in these years was probably due primarily to this. Increasing tree height and more exposed margins will also have played a part.

(c) A broad correlation between rooting depth, tree height and incidence of windthrow is shown.

(d) Observational evidence here, as elsewhere, points to the greater stability of Norway spruce but this has not yet been confirmed by tree pulling studies.

A considerable proportion of the annual loss due to windthrow occurs as sporadic trees throughout most Border spruce crops in the thinning stage. In order to obtain some quantitative data, a survey to investigate causes and distribution of sporadic windthrow of Sitka spruce on a typical Border area at the Forest of Ae was begun. (In this context 'sporadic' implies group of 1 to 5 trees. Larger groups bring many additional factors into play which are considered outwith the scope of this survey). Sporadic windthrown trees are being classified by size and position in relation to drains of various categories, and peat depth.

S. A. NEUSTEIN

Aerodynamic Studies

The wind-tunnel studies were written up jointly with Mr. Walshe of the National Physical Laboratory, and no further studies will be made in the immediate future, until some field observations have been made.

A complex experiment has been planned, which will enable logarithmic velocity profiles, over forest crops, to be measured. Possible sites have been selected, and the experiment will be established in the coming year.

The experiment has been designed, so that comparisons can be made between "crown thinned" and "low thinned" crops, in order to obtain a measure of the aerodynamic roughness of the surfaces of the two types of crop.

The results should fill a gap in the available knowledge of airflow over forests, as well as providing useful material for hydrological investigations.

A. I. FRASER

PROTECTIVE MEASURES

Exclusion of Deer

Roe deer continue to be the primary hazard of regeneration experiments, and exclusion by fencing remains an essential pre-requisite at most forests. In the exposure trials, samples of the various synthetic materials described in the two preceding Research Reports were tested for strength for the third time. This enabled a decay curve to be computed and depreciation rates to be calculated.

Variation within specifications of twine has been found to be greater than expected and no single specification has proved clearly superior. The results to date have been summarised for publication.

Deer Deterrents

In 1963 two experimental sites at the Forest of Ae (Dumfriesshire) and Glenbranter (Argyll) known to be frequently visited by deer were used for a comparison of a number of treatments which have at various times been suggested as possible deer deterrents. These included aluminium foil, steel wire and sheep's wool, twine soaked in 'Arikal', twine soaked in motor oil, and twine soaked in bone oil.

Randomly distributed trees were draped with the various materials and interspersed with untreated control trees. Although a slight short-term protective effect could be detected, none of the treatments at either site have given any promise of practical effectiveness. In all cases at least 50% of the treated plants were damaged between application of the deterrent in spring and the following November—not even the most susceptible period.

S. A. NEUSTEIN

MISCELLANEOUS

Growth Fall-off in Spruce Crops

Studies of current increment continue in plots of Norway and Sitka spruce in areas thought to be marginal for sustained healthy growth of Sitka spruce. In addition, a retrospective study of past growth is being made on trees from Blairadam Forest (Fife) by means of detailed stem analyses, examining radial growth within every internode of the stem. Preliminary findings show very marked reductions in radial and volume increment of Sitka spruce during periods when defoliation by Green spruce aphis, *Neomyzaphis abietina*, were severe, viz. 1949 and 1957–58. Following the latter of these periods, increment has remained at a much lower level than previously, suggesting that some permanent injury was sustained by the trees or the site, since the incidence of aphis attack has been very low in recent years. However, a somewhat similar pattern of growth is also apparent in a Norway spruce stem from the same forest, suggesting a more general, probably climatic, influence. Rainfall during the growing season was near or above average before and during these periods, so future work will include the relationship between growth and other climatic factors such as potential evaporation.

The relationship between growth of Sitka spruce and the incidence of Green spruce aphis is being examined more closely in an experiment at Forest of Ae. Three pairs of plots have been established and measured there, in which aphis populations will be assessed each year and will be controlled by insecticidal spraying in one plot of each pair when numbers appear to warrant this. The crops are growing well on a fairly deep-rooting soil and should be relatively free of major growth fluctuations due to climatic influences.

D. W. HENMAN

Estimation of 'Exposure' by Abney Level

An attempt is being made to assess 'exposure' of high elevation sites by means of Abney Level measurements of the angles to surrounding geomorphic features at 16 points of the compass. This has been done at the thirty-five sites where tatter flags have been exposed over extended periods.

S. A. NEUSTEIN

POPLARS AND ELMS

By J. JOBLING

POPLARS

Varietal Studies

Varietal Trial Plots

The assessment of selected plots continued at major trial areas. The main work was at Quantock Forest, Somerset, and Wynyard Forest, Co. Durham, the two largest trials, where together over 60 plots were measured during the year. At these trials rather more than 140 plots have been assessed, some for the second time, during the past three seasons. As on previous occasions the outstanding measurements were obtained from the plot of 'Androscoggin' poplar (*Populus maximowiczii* × *trichocarpa*) planted in December 1949, at Quantock Forest. This, at 14 years of age, had an average height of 86½ feet, an average girth at breast height of 40½ inches, with a basal area per acre of 77 square feet (Hoppus measure) at a stocking of 109 trees to the acre. The plot volume was not measured, but from figures obtained in 1962 it was estimated that the volume per acre exceeded 2,300 hoppus feet at 14 years. The largest tree was 95 feet tall, with a breast height girth of 44 inches, and seemed capable of reaching 100 feet by the end of the fifteenth year from planting. None of the trees appeared to be infected by bacterial canker. (See Table 3).

The hybrid *P. maximowiczii* × *trichocarpa* is well represented in trials and at some sites two or more related clones of the cross have been planted. The clones so far established of this origin are 'Androscoggin' 'O.P.42', 'O.P.388' and 'North West A'. They appear similar in rate and habit of growth and (on preliminary evidence) in timber quality, and are virtually impossible to separate botanically. They differ somewhat in susceptibility to bacterial canker. But until more is known of the conditions under which bacterial infection occurs none should be planted on a commercial scale. The canker status of 'Androscoggin' is briefly discussed in "Apparent Variations in the Resistance of Poplar Clones to Bacterial Canker" in Part III of this publication. In Tables 3 and 4 the performance of 'Androscoggin' and 'O.P.42' is well illustrated in relation to the growth of other clones planted at the same time. In both trials, at Quantock Forest and Bedgebury Forest, Kent, each plot was represented initially by 16 trees at a spacing of 18 feet × 18 feet (134 trees per acre), but occasional deaths after planting and, in the Bedgebury Trial, the removal of competing trees a year or two before assessment, have reduced the stocking in some plots.

The clones are not replicated in the Quantock trial but a standard for comparison is provided by the behaviour of *P.* 'robusta' interplanted between the plots. These, also at 10 years of age, have generally reached a height of 40 feet and a girth at breast height of 21 inches. Local waterlogging has affected the growth of several trees of the last three listed clones, but even the better specimens in these plots are scarcely bigger than the control trees of *P.* 'robusta'. The three fastest growing clones are Balsam hybrids; with the exception of the two selections of *P. trichocarpa*, the remaining clones in the list are Black hybrids. It is interesting to note that more than half the trees in the plot of

Table 3

POPLAR TRIAL PLOTS—QUANTOCK FOREST, SOMERSET
HEIGHT AND GIRTH AT 10 YEARS

Clone	No. of trees per acre	Average height of crop (ft.)	Average girth of crop (ins.)	Basal area per acre (sq. ft.)
O.P. 42	134	66½	22½	62·4
Rochester	126	46½	24	31·5
berolinensis × maximowiczii	134	46	26½	41·0
Reinbek LD 118	134	41	21½	27·1
trichocarpa HT	134	39½	19½	21·9
regenerata B	134	37	20	23·4
Munich R	126	32	13	9·5
trichocarpa T3	134	26	12	8·3
serotina LO 130	134	23	9½	5·3

'O.P.42' have reached a breast height girth of 32 inches; this is the normal lower size limit for veneer logs for the match and basket industries.

In Table 4 data are listed for 12-year-old plots at Bedgebury Forest, where the first thinning was carried out at the end of 1960 at the age of 10 years. All the clones are Hybrid Blacks with the exception of 'Androscoggin'. Many of the Casale hybrids of Italian origin do well on the better southern sites, but in the north and west of Britain, especially on the more acid soils in high rainfall districts, they often lack vigour and may even fail to make a useful crop. Some of them have a poor form on exposed ground. The radial growth of *P.* 'gelrica' at this site is encouraging. This cultivar is said in the Netherlands to produce a larger volume of timber per acre in a given time than any of the older hybrids such as *P.* 'robusta' and *P.* 'serotina'. Its early behaviour in this country had hardly confirmed this opinion, but some older plots such as this are now tending to grow very rapidly in girth and *P.* 'gelrica' could well be an excellent prospect for Britain also.

Table 4

VARIETAL TRIAL PLOTS—BEDGEBURY FOREST, KENT
HEIGHT, GIRTH AND VOLUME AT 12 YEARS

Clone	No. of trees per acre	Average ht. of crop (ft.)	Average girth of crop (ins.)	Basal area per acre (sq. ft.)	Vol. per acre (H.ft. O.B.)	Thinning vol. per (acre (H.ft. O.B.)	Total vol. production per acre (H. ft. O.B.)	Mean annual increment per acre (H. ft. O.B.)
Androscoggin	67	57½	33	32·1	751	447	1198	100
Casale 30	126	51½	31	52·0	1010	35	1045	87
gelrica HA	101	45½	33½	49·5	758	239	997	83
Casale 78	84	48	31½	35·7	635	330	965	80
Heidemij	134	47½	23	30·9	555	—	555	46
Casale 72	134	39	16	15·1	223	—	223	19

A preliminary examination of the timber of certain balsam poplars was undertaken during the year, particularly to ascertain their potential usefulness for the match industry. The tests were carried out at a match factory, and normal splint veneers, such as are taken from Canadian aspen, were obtained from a number of sample logs. The clones tested were:—*P.* 'Androscoggin' from Greskine Forest, Dumfries, and Brahan Castle Estate, Ross-shire; *P.* 'O.P.42', Stenton Forest, East Lothian and Berwick; *P. trichocarpa* CF, Hallyburton Forest, Angus and Perth, and Stenton Forest; *P. tacamahaca* × *trichocarpa* CF, Wynyard Forest, Co. Durham, and *P. nigra* × *trichocarpa*, Stenton Forest. The trees were aged from 10 to 14 years and yielded billets within the usual veneering size range. All the clones peeled satisfactorily, often to a 3 to 4 inches core, and there was no evidence to suggest that balsam poplars require a veneering technique markedly different from that used for aspen or the Hybrid Blacks. The veneers themselves varied from clone to clone and there were more defects in *P. trichocarpa* CF and *P. nigra* × *trichocarpa* than in the others. Many of the defects were attributed to knots and insect activity, however, and improved veneers from these two clones could no doubt be obtained. With all clones the colouring was very satisfactory, being pale yellow to white, and was measurably lighter than the more yellow veneers from aspen and various Hybrid Black cores being cut at the same time. The grain in all cases appeared to be straight, and irregularities in the veneer surface, due to the presence of reaction wood in the stem, were not common. 'Androscoggin' and 'O.P.42' gave the best veneers for both colour and freedom from marks and, in each case, a considerable proportion of the wood appeared to be devoid of any defects. It was particularly noticeable that neither of these clones showed markings due to the occurrence of root initial traces that are a common feature of many Hybrid Black poplars. It is hoped later to publish information on breaking tests carried out on splints prepared from the veneers of the five clones.

Varietal Collection

Seven selected clones were introduced during the winter, from Rumania, for inclusion in disease trials and the populetum, and the collection increased to a total of 408 clones.

Populetum

Seven clones were planted during the winter, bringing the total to 291.

Silvicultural Experiments

Establishment Studies

Interesting data are again available from experiments at Lynn Forest, Norfolk, and Creran Forest, Argyll, on the effects of mulches applied to newly planted poplars. In both experiments three mulch materials were used, namely cut vegetation, bark peelings and used fertiliser bags, and in each case the materials were maintained in a fresh condition for one, three or five years from the time of application. With both cut vegetation and bark peelings a comparison was made between two depths of mulch, namely six inches and twelve inches. After six growing seasons all mulch materials had significantly increased growth, cut vegetation being the most beneficial and fertiliser bags the least, and the thicker mulch had increased the height of the trees more than the 6-inch mulch. The data also suggest that the beneficial effects of mulching continue for some seasons after the mulch has ceased to be maintained, as trees mulched for only three years were of the same height at the end of the sixth season as trees mulched for five years.

It could be concluded that the maintenance of mulches for an additional two seasons, from three to five years, would only be of benefit if the materials were more widely distributed around the trees than was the case in the experiments. The mulches of all materials were spread only to a radius of two feet from the stem.

Spacing

The closest spaced plots in the first-planted experiment in the series, at Lynn Forest, were thinned during the year. Four plots, planted initially with the trees at 8 feet × 8 feet spacing, had their stocking reduced by half, from 680 trees per acre to 340, with the removal of alternate diagonal rows. The experiment, laid down in 1953, is designed to compare the volume production, and final crop yield, of poplar planted at the initial spacings of 8 feet, 14 feet, 18 feet and 26 feet, and thinned on the onset of competition. Regular girth assessments are carried out in the plots to detect any fall in the rate of radial growth at or before canopy closure.

Pruning

The use of vernier girth bands again allowed of accurate comparisons being made of the effects of pruning on radial growth. Bands fitted to trees at Alice Holt Forest, Hants, in the early part of 1962, when pruning was carried out, were retained in position throughout the 1963 growing season and, as in the previous year, confirmed a reduction in radial growth rate as intensity of pruning increased. Trees pruned to three-quarters total height not only had a slower rate of growth during the peak growing period from mid-May until the end of August, than trees pruned to one-quarter total height, but they terminated growth earlier at the end of the season. Trees pruned to one-half total height were intermediate in growth rate between the two extremes. Over the two-year measurement period, trees pruned to only one-quarter total height increased in girth at a point on the stem 2 feet above ground level by 6·3 inches, those pruned to one-half total height increased by 5·0 inches and those pruned to three-quarters total height by only 3·8 inches. There are some advantages in heavy pruning and in practice it is desirable to obtain a clear stem to 20 or 30 feet as soon as possible. However, since the effects of a single heavy pruning on growth rate are appreciable and immediate and, with many cultivars, lead to considerable epicormic growth, the removal of a large proportion of the crown has to be avoided. The present recommendations of regular pruning to one-third to one-half total height may be adequate, since a lighter pruning than this results inevitably in a large knotty core. It is hoped that long-term experimentation now in progress will soon provide confirmatory data.

Distribution of Cuttings

Over 23,000 nine-inch cuttings, largely of the recommended cultivars, were distributed during the winter to Forestry Commission and trade nurseries and to private estates. Over 7,000 of these were cuttings of *P.* 'robusta', a number considerably in excess of the disposal of *P.* 'eugenei', *P.* 'laevigata', *P.* 'gelrica' and *P.* 'serotina' together. Cuttings of trial clones were also sent to University workers in this country, as well as to research workers in East Germany, West Germany, India and Ireland.

Bacterial Canker Investigations

Work continued on the testing of clones for resistance to bacterial canker. A summary is included in the section on 'Forest Pathology' following.

ELMS

Clonal Collection

Sixty-six clones were propagated during the year, primarily to obtain plants for the clonal stool beds and disease trials, though six of the clones were raised on a substantial scale for silvicultural studies. Sixty-two clones are now established in stool-beds, for the production of softwood cuttings for propagation, including four clones at Westonbirt Arboretum, Gloucestershire, and nine at Kennington Nursery, Oxford, for raising large numbers of plants for field trials. The same sixty-two clones have also been planted in a disease trial in a nursery adjoining the Forest Research Station.

A collection of clones of outstanding merit is being established at Silk Wood, Westonbirt Arboretum. Each clone is to be represented initially by a forest plot extending to nearly one half acre. The first plot was planted during the winter, using a clone known at the moment only as 'RT'. This appears to be a complex hybrid derived from *U. carpinifolia* × *glabra* and was one of the first selections made in Britain after the dramatic spread of elm disease (*Ceratocystis ulmi*) between 1928 and 1932. It is moderately resistant to elm disease and grows quickly, but has a heavy, spreading crown. The original selection was made at Quendon, Essex, in a line of roadside trees. Other, more recent, selections made in this country will be planted later, to include selected clones of the major species and hybrids that occur in Britain, while a number of artificial hybrids obtained from the Netherlands will also be planted.

Propagation

During the summer, large-scale propagation of softwood cuttings, using the 'mist' technique, was attempted for the first time at Kennington Nursery. The use of peat pots and unit plastic trays greatly facilitated handling of the rooted cuttings after their removal from the mist frame, and the number of surviving plants at the end of the growing season was nearly 2,000, out of a total of 3,000 cuttings inserted. Since many of the cuttings were below the quality required for mist propagation, having been taken from recently planted stools, it is expected that the 'take' will be substantially increased in other years as stool growth becomes more vigorous. Because the cutting material varied so much in quality, it was not possible to compare the rooting ability of different species and hybrids, and at least for a further season the various selections will receive the same mist and nursery treatment. Substantial numbers of rooted softwood cuttings were also raised at Alice Holt and at Westonbirt Arboretum.

There is appreciable evidence that softwood cuttings inserted in 'mist' during the early part of the growing season (May-June) have a higher rate of survival and give bigger plants than cuttings taken later. During the summer an experiment was undertaken at Alice Holt to study the relationship between time of insertion and cutting behaviour, involving the collection and insertion of material at two-weekly intervals. To find out whether cuttings obtained in early season can be stored (to await space in the mist unit for example) to give the same survival and growth as cuttings inserted immediately after collection, material was placed in a cold chamber, at 3°C., for periods of from 2 to 10 weeks. Unfortunately, a local fall in water pressure at different times during the experimental period led to water shortages in the mist unit and appreciable numbers of cuttings failed that might otherwise have rooted, and only the height growth of the surviving plants provided a means of comparison between treatments. Nevertheless there was confirmatory evidence that cuttings inserted in June gave better plants than cuttings inserted in July and August, while cuttings taken in June and stored for two or four weeks before insertion also grew well. Plants from cuttings stored for a longer period than this, or stored for a similar period when taken in July and August, were smaller at the end of the year than all others. The plants have been lined out to ascertain if treatment effects continue into the second year.

The propagation of elm from hardwood cuttings again proved difficult and on current, though necessarily limited experience, there is little prospect of the method having any general application. There is an indication, however, that storage of cutting material in a cold chamber at 3°C. for a period of 12 weeks prior to insertion improves survival, and the use of this chilling treatment is being studied further. Irrigation and shade may also be beneficial.

The propagation of sucker growth to obtain planting stock was also studied during the year. It is well known that suckers are difficult to establish when planted direct in the forest, while even in the nursery their survival is uncertain and die-back is frequent, even of apparently healthy plants. At Alice Holt an experiment was undertaken to observe the nursery behaviour of suckers of varying quality as well as the effects, on survival and growth, of cutting the plants back to the region of the root collar after lining-out. This practice, when used with aspen (*Populus tremula* and its related species and hybrids), improves both the habit and vigour of the plant. The first year's results with English elm, *Ulmus procera,* show that suckers that have developed an extensive root system, particularly of a fibrous character, while still attached to the parent tree, have a better survival after lining out than suckers that have only a rudimentary root formation. Since the size and habit of the sucker shoot cannot always be related to the root development beneath, well rooted suckers cannot readily be selected in the forest or hedgerow. Shoot quality, on the evidence of this experiment, cannot be used as a guide to nursery behaviour, since both plants with a single vigorous stem and those with a number of proliferating shoots of the type found in shade in woodland conditions, survive equally well if possessing a good root system. Cutting back shoot growth improved both survival and habit, particularly of initially weak suckers.

Establishment Studies

Two experiments were planted during the winter at Alice Holt Forest to study the establishment of rooted softwood cuttings. In one a comparison is being made of the behaviour of different sizes of transplanted stock, and in the other, one-year rooted cuttings are being compared with selected transplants of uniform size. In both experiments the use of selective weedkillers in elm plantations is being tested.

In the establishment experiment planted at this site in 1962, in which early field behaviour of two ages of transplanted stock are being compared, all trees survived and grew vigorously in the second season. But the rooted cuttings transplanted for one year increased in height more than the stock transplanted for two years, and since the younger age of plant also grew better in the first season there appears to be no advantage, on this evidence, of using the initially taller, though less vigorous older transplant. Data for the two growing seasons are given in Table 5. It will be noted that the mean height of the older plants showed a slight decrease in the first season, as the result of several trees dying back. Those that increased in height did so slowly however. All the plants were of the Commelin elm, *U. hollandica* cv. 'Commelin'.

Table 5

DIFFERENCE IN HEIGHT OF TWO AGES OF TRANSPLANTED ROOTED CUTTING OVER TWO GROWING SEASONS

Age of Plant	Mean Height in Feet		
	March 1962	October 1962	October 1963
Rooted cutting transplanted one year	3·8	5·4	9·3
Rooted cutting transplanted two years	5·7	5·5	8·9

Disease Testing

Several recently selected clones were tested for their resistance to elm disease in the trial in the Research Station nursery and useful data were obtained. The work is discussed in the section on 'Forest Pathology' following.

FOREST ECOLOGY

By J. M. B. BROWN

Pinus nigra: Corsican Pine and Related Pines

The accumulated data on the growth and health of Corsican pine and related pines of the species *Pinus nigra*, in relation to site factors, have been examined and the recent literature studied as the foundation of a full report on this tree in Britain. A few supplementary field observations on the die-back disease associated with the fungus *Brunchorstia pinea* (Karst.) v. H.(*Scleroderris lagerbergii* Gremmen) confirmed the conclusions outlined in the 1963 *Report on Forest Research*. During a visit to Denmark in the summer the opportunity was taken of seeing some of the plantations on the coastal sands of West Jutland, where *Pinus nigra* of Austrian origin contributed largely to the early plantations made in the second half of the nineteenth century. The northerly climate proved too harsh and most of the trees died when about 20 years old: but the vigour and good colour of the scattered survivors at once confirmed the evidence from Britain of the importance of good ventilation in promoting resistance to disease and showed the strong resistance of Austrian pine to gales and salt spray. Danish foresters seldom plant trees within one mile of the sea, the work of stabilising the mobile sand being left to the native marram grass (*Ammophila arenaria*).

Fall-off in Growth of Sitka Spruce in South Wales

Several young forests in South Wales and Monmouthshire have been examined with the object of throwing light on a disturbing local fall-off in the rate of growth of Sitka spruce to which attention was drawn by the supervisory staff. The regional climate appears well suited to the tree, but there are several adverse factors which affect different localities in different degree, for example:

(1) Frequent strong winds on the higher land and near the coast.

(2) High amounts of sulphur dioxide and other pollutants in the vicinity of the collieries and main industrial centres.

(3) Prevalence of shallow soils of poor permeability, in which the development of a deep root system capable of supporting large trees may be inhibited.

(4) Low fertility, especially on leached soils of the Millstone Grit and Pennant Sandstone formations.

(5) General lowering of the water table in the area covered by deep coal mines.

(6) Frequent attacks by the spruce aphis, *Neomyzaphis abietina*.

A little reconnaissance has been carried out, but much more investigation is needed before any hypotheses can be put forward.

FOREST SOILS

By W. O. BINNS, W. H. HINSON, R. KITCHING, and D. F. FOURT

Current research in the Soils Section is concentrated on the following main lines. The Section took over full responsibility for fertiliser trials in the South in July 1963, on becoming independent of Silviculture; formerly the Section had been concerned only with foliage analysis in connection with these trials. For convenience, however, the nutritional work is grouped under "Silvicultural Investigations", page 20. Research on soil moisture relations of trees is being done on two different types of site: stands in low rainfall areas with light or calcareous soils, where the water consumption and growth of different species is being investigated in relation to soil type, soil moisture, and climate; and drainage experiments on newly planted heavy soils, where changes in soil moisture and run-off are being studied, in collaboration with the Silviculturists.

Soil Moisture in Woodlands

The investigations of soil moisture in woodlands are aimed at determining the effect of available moisture and climate upon tree growth and also the estimation of the water consumption of different species. Some of the equipment used is shown in Plate 1.

Studies have actively continued in a sandy loam at Bramshill, Hampshire, and in a chalk down site at Queen Elizabeth Forest, near Buriton, Hampshire. Encouraging results have been obtained with soil moisture blocks which have clearly shown the drying patterns on these sites. These results have prompted the extension of the studies to an additional site at Thetford Chase during the winter 1962/63 and preliminary results are reported below. Work is also in hand to cover other soil and site conditions. Further work is planned to supplement the present Bramshill studies in order to provide facilities for detailed analysis of soil moisture movement.

Sand on Chalky Boulder Till, Thetford, Norfolk

The soils of Thetford Chase are locally regarded as being susceptible to drought, particularly where the chalky till is near the surface. It has also been considered possible that underplanting of beech in pine may result in a change of litter form, with better moisture retention. In order to make a rational assessment of the soil moisture regimes in this area, plots have been selected and electrical soil moisture blocks, together with tree girth bands, have been installed. By these means it will be possible to study the soil drying patterns in relation to the growth of the crop.

The sites selected are in pure Corsican pine planted in 1926, in an adjoining similar stand which was underplanted with beech after a fairly heavy thinning in 1955, while for general comparison there is an adjoining area at present under grass. The latter is a strip running North to South about 100 yards wide and over ½-mile long. The afforested plots have a height of 45–50 ft., and apart from the grass strip which is to the east, form part of a large area of crops of comparable height on level ground. The average rainfall is about

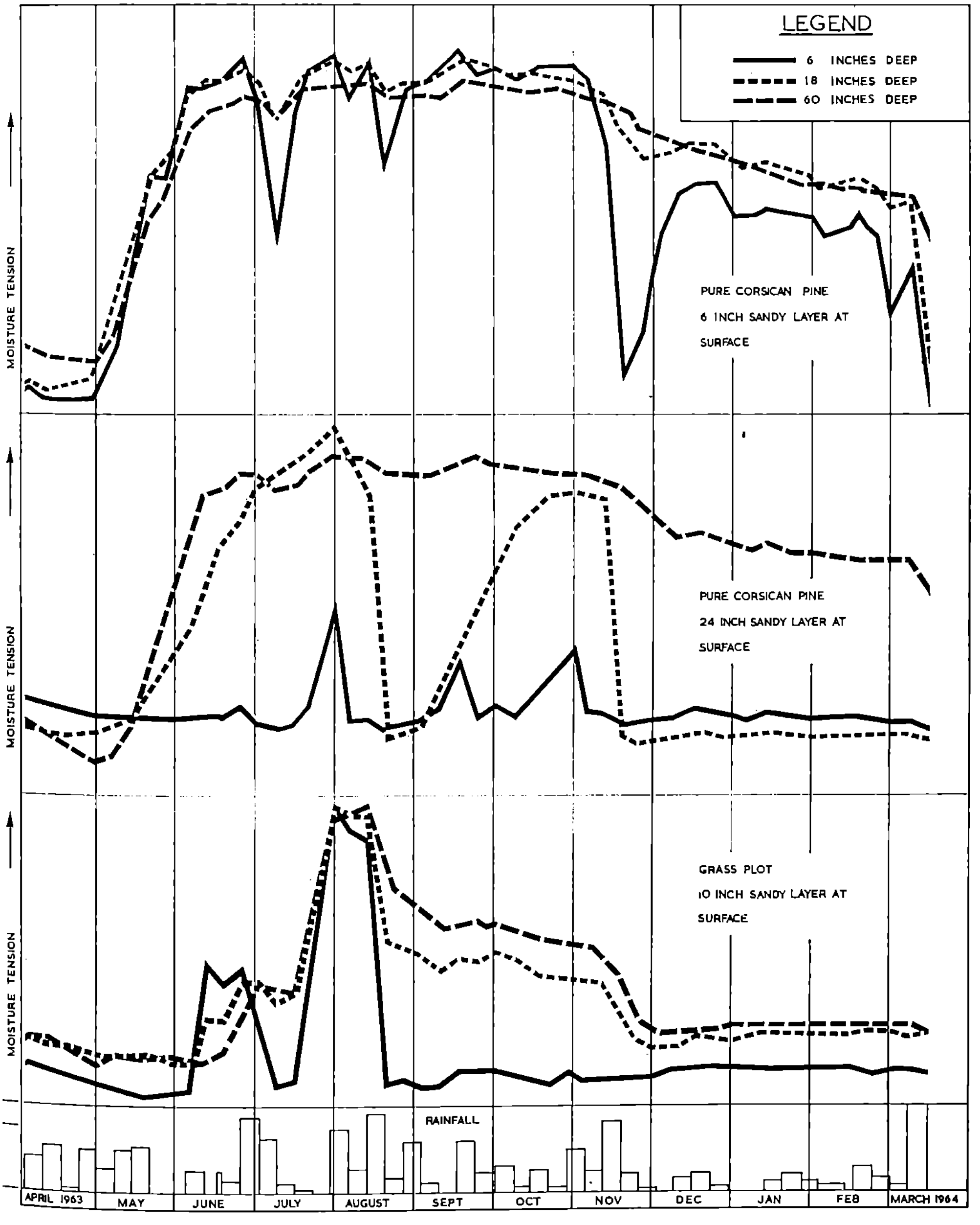

FIGURE 2. Soil Moisture in Woodlands: Results of the first year of observation, April 1963—March 1964 inclusive, referred to in the text

22 inches. The soil consists of a shallow but variable thickness of sandy material grading into a fairly compact chalky Gipping Till. The transition layer contains abundant chalk as well as sand, and is fairly soft and loose. The electrical soil moisture blocks have been installed at depths of 6, 12, 18, 36, and 60 inches, at 11 locations, the depth of the sandy layer ranging from 6–24 inches. 20 girth bands have been fitted to trees near the soil block stacks.

Soil block resistances and tree girths have been measured at weekly intervals throughout the year.

Some of the results of the first year of observation are shown in Figure 2. Some outstanding features of the soil moisture curves are worth noting:

(i) There has been little difference between the soil drying in the stands of pure Corsican pine and those underplanted with beech, and therefore only 'pure pine' drying curves have been shown.

(ii) The blocks in the chalky till indicate that there is never much tension gradient in this part of the profile, the electrical resistance of the blocks changing at the same time and by almost the same amount at each depth. This holds regardless of the depth of the sand above and is indicative of the high moisture conductivity of the chalk.

(iii) The electrical resistance of the blocks in the sandy and transitional layers shows a similar pattern of trends at each depth but the tension gradient is usually greater than in the chalk.

(iv) The blocks in the sand layer are much more affected by summer rain than those in the chalk.

(v) There is a consistent and substantial difference between the afforested and grass plots, the latter drying for a shorter period.

(vi) There is no zone of constant moisture tension in the region of the lower blocks as in the loam at Bramshill.

It seems reasonable to suppose that the tensions developed during the summer were due to transpiration rather than continued vertical drainage. Details of the sequence of the drying cycle suggest that there is abstraction of water by crop roots in the chalky till. The chalk is evidently a medium of high moisture conductivity so that even sparse rooting of this zone may be important.

Sandy Loam at Bramshill, Hants.

Results obtained in 1962 in the Corsican pine plots indicated that drying occurred to a depth of 42–66 ins., the depths of two of the deeper moisture blocks. To enable both the maximum depth of drying to be located accurately and the actual date of rewetting of the profile to be found, blocks were emplaced at the intermediate depth of 54 ins. These were inserted in inclined auger holes in the early spring of 1963. Similarly, extra blocks were placed in the Douglas fir plots at a depth of 33 ins., which is 9 ins. deeper than the lowest blocks to show drying effects the previous year.

The growing season at Bramshill was cooler and less sunny than 1962, particularly during August, and the rainfall was above average. These conditions led to a smaller soil moisture deficit than in 1962. The effect was clearly to be seen in the four stacks of blocks in the Douglas fir plot, two of which hardly dried at all, none of the new blocks showing any sign of drying.

However, seasonal differences did not prevent the original set of blocks in the Corsican pine showing patterns of drying very similar to 1962. Drying at the 54 in. level, shown by the new blocks, commenced in August and continued beyond the end of the year, while all other layers rewetted. The 54 in. layer fully regained its initial moisture tension only in March. The difference in the drying patterns of the two plots is evidently even greater than previously reported.

During 1963 the Douglas fir girth increments were distinctly greater than in 1962, while those of the Corsican pine were slightly less.

Chalk Down, Queen Elizabeth Forest, Buriton, Hants.

The comparison of soil drying under beech and grass at this site (*Rep. For. Res., For. Comm.*, 1963) has been continued. The soil moisture data for the year under review is very similar to the previous year. The growth curves for the beech, based on weekly readings of vernier girth bands, did not show much variation in growth rate through the season in 1962, and in 1963 the girth bands have been read twice a week. It is now evident that pauses and even periods of shrinkage are occurring at this site but that weekly readings are not frequent enough to pick up these effects. The rainfall at this site for April 1963 to April 1964 was 46 inches.

Electrical Resistance of Tree Stems

A potentiometric technique has been applied to measuring the electrical resistance of the stems of trees of a number of species connected to the laboratory by telephone cables. Gypsum blocks are being used to monitor the local soil moisture conditions and in addition, the measured trees have girth bands fitted.

The electrical resistances of the trees have exhibited widely different trends. A Douglas fir for which the electrical resistance was measured at breast height, showed a most pronounced increase at the end of June when soil moisture tensions were rising and growth had fallen off. The electrical resistance reached a maximum at the end of July after which the soil moisture tensions were somewhat reduced. A beech showed peaks of electrical resistance coinciding with dry periods, June 2/9 and July 28/August 2. Other species exhibited less clear trends. On some days during the year the electrical resistance measurements were made throughout the day to determine whether diurnal variations are observable. In general no significant trends were observed throughout the day, even on days when transpiration might have been expected to be high.

The trends that have been observed in electrical resistance of tree stems have indicated that stresses occurring in some species, and affecting the electrical resistance, follow a roughly similar pattern to soil moisture stresses.

Garnier Gauges at Alice Holt

As in previous years (See *Rep. For. Res., For. Comm.* 1962 & 1963) the gauges at Alice Holt have been read daily at about 9 a.m. G.M.T., for seepage and rainfall, and measured waterings have been made when necessary.

Waterings are always made unless the soil surface of the lysimeter is frozen, or snow covered—as it was for long periods early in the current year,—or if heavy and persistent rain is actually falling at 9 a.m. An examination of the data shows several unusual features. The year is taken from the onset of frosty conditions, and the period December 19, 1962 to March 31, 1963 is calculated together. Few waterings took place over this period except in March, and the gauges were drained of much of their free water.

Table 6

GARNIER GAUGE RECORDS, ALICE HOLT, 1963

Month	Potential Evaporation Inches (P.E.)			Rainfall inches Alice Holt	Sunshine	
	Lysimeters		Calculated Value*		Daily mean hours (from tables*)	Daily actual hours 1963
	A	B				
January †			0·25	0·82		
February †	0·75	0·82	0·40	0·75		
March †			1·00	4·75		
April	1·82	1·61	1·84	3·63	5·05	4·52
May	2·28	2·37	3·12	1·34	6·20	6·52
June	3·11	2·72	3·32	1·76	6·90	5·75
July	3·42	3·12	3·61	1·80	6·50	6·05
August	4·96	5·17	2·65	4·25	6·30	4·97
September	1·50	1·32	1·61	2·50	4·60	4·38
October	1·57	1·02	0·65	2·20		
November	0·87	0·41	0·20	6·03		
December	0·23	0·20	0·15	0·84		
Totals 1963	20·51	18·76	18·80	30·67		

Notes

* Tech. Bull. No. 4 M.A.F.F.

† From December 19, 1962 included.

During the summer, sunshine was below average, and rainfall somewhat above. The calculation for August shows the largest difference between Gauge and Potential, and this is ascribed partly to the low sunshine—affecting the Potential calculation—and partly to the effect of rainfall. The dry fortnight in July caused some drop in storage in spite of waterings, but this was made up in early August by heavy rain. More rain late in the month probably did not raise the seepage figures till early September.

The gauges continue to show their limitations, especially where short term calculations are concerned.

In 1963, agreement between the two gauges was poor, compared with previous seasons, for reasons unknown.

Drainage Studies

Rainfall and run-off have been recorded throughout the year at Halwill, Devon, where flow gauges have been installed on the outfalls from plots with different drain spacings. Integration of the flow recorder charts has presented several problems, the chief of which was the production of a suitable instrument for this purpose, incorporating a means of correction for the non-linear height/flow characteristic of the recorder. This has now been achieved by fitting a cam drive to a planimeter, and this instrument has made the integration much less tedious.

FOREST GENETICS

By R. FAULKNER, R. B. HERBERT, and
A. M. FLETCHER

Survey of Seed Sources

This survey was continued during the late spring and early summer of 1963. As in 1962, most of the effort was directed to the location of suitable sources of Lodgepole pine planted during the period 1935–40. The survey resulted in the selection of nineteen new sources totalling eighty-seven acres, most of which were derived from seed originally imported from the 'inland' Prince George region of British Columbia. In addition sources of Corsican pine, Sitka spruce, Douglas fir, Western red cedar, Chile pine (*Araucaria araucana*) and ash were registered.

The present *Register of Seed Sources* now contains 598 classified sources totalling 9,368 acres. A large proportion of the older seed sources of some species, particularly Scots pine, European larch and Douglas fir, are mature and unsuitable for management and regular seed collections. It is, therefore, proposed to revise and re-issue the *Register*. The revised *Register* will contain a list of all seed orchards and seed sources each of which will be categorised according to its quality and suitability for regular collections and conversion into a *seed stand* or *seed production area*. Preparatory work has already begun on this revision. The revised *Register* will be presented in loose-leaf form so that future alterations can easily be made. There will be four categories, namely:

(a) Seed orchards.

(b) Plus and Almost Plus sources over five acres in size, containing trees less than 100 feet tall, which are easy or only moderately difficult to climb and less than sixty years old. These sources are those which have been converted to seed stands or which are in the process of conversion. In addition, hardwood sources with trees over 100 feet tall and over 60 years of age, of species from which seed is obtained by collection from the ground, will be included in this category. In special circumstances both Normal and small sources will be included, for those species in the *Register* which are poorly represented on an acreage basis, until adequate areas of higher quality become available.

(c) Plus and Almost Plus seed sources less than five acres in size, together with Normal seed sources with trees which are less than sixty years old, under 100 feet tall and easy or only moderately difficult to climb. Such sources are not usually recommended for conversion to seed stands and in practice should only be used for seed collections when seed reserves are low.

(d) Coniferous seed sources and sources of ash and sycamore over one acre in size and classed as Plus, Almost Plus or Normal, with trees which are over 100 feet tall or more than sixty years of age. These sources are unsuitable for conversion to, and management as, seed stands; but they could yield large quantities of easily obtained fruit if fellings are timed to coincide with the ripening of cones during a good seed year.

1963 was a poor seed year for most species, except for Scots pine in East Scotland where moderate cone crops were reported in the Moray Firth area.

Selection of Plus Trees

General. Further selections of outstanding phenotypes (Plus trees) and other trees of special interest (Special trees) were made during the year. The total number of Plus and Special trees of all species selected and recorded has been slightly reduced during the year to 3,358. The reduction was caused by the loss of several parent trees by felling or windthrow, and before they could be vegetatively propagated.

Sitka Spruce. In addition to the routine survey of Plus trees, a procedure for selecting and recording the characteristics of candidate Plus trees of Sitka spruce on edge-punched cards was thoroughly tested at Glenbranter Forest, Argyll, and in Kerry and Dovey Forests, North Wales. The survey, which was used as a training exercise for all field staff, resulted in the location of forty-nine candidate Plus trees. This represents a very high standard of selection and approximates to one in 750,000 of *all* seeds originally sown. The Wood Anatomy Section of the Forest Products Research Laboratory at Princes Risborough co-operated in the project by making wood specific gravity determinations on the 21st-25th annual rings, and tracheid length on the 26th annual ring from the pith. Wood samples were taken from 12 mm. cores at breast height from each candidate Plus tree. Results showed that only fifteen per cent of the candidate Plus trees had a specific gravity above 0·34. This figure represents the calculated average for Sitka spruce timber grown in Britain, though it must be remembered that few trees exceed forty years of age. All candidate trees having higher-than-average wood densities will be vegetatively propagated and used in seed orchards. Of the nine trees with a specific gravity of over 0·34 seven had tracheid lengths above 2·5 mm. Within the entire collection of candidate Plus trees tracheid lengths ranged from 2·2 to 3·2 mm. and eighty-two per cent of the trees had tracheid lengths above 2·5 mm.

Tree Banks

Work started on the establishment of new tree banks of Western red cedar and beech at Alice Holt and further additions were made to the National Collections of Plus and Special trees of two-needled pines, the larches and Douglas fir. It was decided to restrict the Scots pine tree bank at Alice Holt to English and Welsh clones, and to those Scottish clones which have demonstrated good general combining ability in forest progeny trials. As a result some Scottish clones have been removed to create the necessary space.

Vegetative Propagation

Some 11,113 grafts were attempted during the spring of 1963 of which 6,590 had survived to the spring of 1964. This represents an overall success of sixty-four per cent. Most of the larch, Scots pine and Lodgepole pine Plus trees have now been propagated by grafting and successfully established in tree banks and seed orchards. As a result the annual demand for nursery raised grafts is expected to fall during the next few years. The production of new grafts should keep pace with the rate of future plus tree selections and for this reason it is intended to concentrate future grafting in the main propagation centre at Grizedale, Lancashire, and to reduce the grafting programmes at Alice Holt and Bush. Grafting at Westonbirt ceased during the year.

An experiment at Grizedale designed to test the effects on the rooting of Sitka spruce cuttings obtained from fifteen parent trees, of season of collection, position on the tree, temperature and rooting media, winter chilling and day length, failed to give a clear answer. A modified experiment will be undertaken in 1964.

Cuttings of Western red cedar, Leyland cypress, Western hemlock were inserted in propagation frames fitted with mist and bottom heat equipment. In all 39,000 cuttings were inserted. Expanded polystyrene was successfully used as an insulating material in a propagation frame at Grizedale. At the time of installation new wiring was introduced and media temperatures of 75°F. can now be obtained, even during winter months.

Controlled Crossing

In spite of a generally poor flowering season a limited amount of pollination work was carried out in the hybrid larch seed orchards at Mabie, Grizedale and Alice Holt. The programme included a 4 × 4 diallel crossing pattern (excluding selfs) from which seed has been obtained to produce sufficient plants for a progeny test on at least two forest sites. Investigations into methods of extracting and storing larch pollen were undertaken at Mabie and Alice Holt.

Moderately heavy crops of female flowers in the Scots pine tree banks at Newton and Alice Holt permitted a large-scale controlled pollination programme to be carried out. A mixture of pollen from several selected progenies of Windsor origin was used in a polycross test in which 5,864 female flowers were isolated. This was the first large-scale pollination programme in Britain in which pollen stored for twelve months at −5°C. has been used.

The owner of Altyre Estate, Moray, has kindly granted permission for 11 Scots pine Plus trees to be provided with permanent steps to afford easy access to the crowns for regular pollen collections. Eventually these trees will be stabilised with guy ropes to minimise the risk of windthrow. Providing satisfactory yields of viable seeds are obtained from controlled pollinations with stored pollen, then these trees will be used to provide a standard pollen mixture for many controlled pollination experiments in the future.

A series of minor investigations at Newton on flower isolation techniques included satisfactory trials of a variety of flower isolation bags of different sizes and shapes manufactured from 'Terylene'. A trial of isolation tubes manufactured from expanded polystyrene was unsuccessful. A small project was also initiated to determine the effects of abrasion on the development of flowers and cones previously subjected to different degrees of damage. Abrasion of flowers frequently occurs in practice when protected flowers rub against the sides of pollination bags during windy periods.

Formation and Management of Seed Orchards

A summary of the seed orchard work carried out during the period 1952 to March 1964 is presented in Part III of this *Report*. A group of seed orchards, at Clanna in the Forest of Dean, is shown in our Plates.

Flower Induction Experiments

Ride-side trees of Scots pine, Corsican pine, Lodgepole pine, Japanese larch, Douglas fir and Sitka spruce, growing on hillsides with a southerly aspect, were used in a total of twenty-six experiments designed to test the flowering response of conifers to fertiliser applications. The fertilisers under test were applied in March 1962 at rates equivalent to 118 lbs. N., 49 lbs. P., and 93 lbs. K., per acre and at two, three and four times these rates. Fourteen of the experiments were concerned with Japanese larch, Douglas fir and Sitka spruce, and these were assessed in autumn 1963 by making cone counts in each treatment plot of five trees. Cone production was extremely low on all trees and in no case was it increased by any of the fertiliser treatments. A second assessment of cones will be made in autumn 1964 when the pine crop cone will be assessed for the first time. A more detailed experiment on 243 sixteen-year-old Scots pine trees is being undertaken at Thetford in which 'Nitrochalk' (21%N), superphosphate (8·7%P), muriate of potash (50%K) and magnesium sulphate (10%Mg) fertilisers are being applied both singly and in factorial combination at three different rates within the range of 0.72 ozs. per tree. A similar experiment was started at Culbin, Morayshire in 1962 in a thirty-two-year-old stand. This experiment will be assessed for flower response to the fertiliser treatments in autumn 1964.

Progeny Trials

Two Lodgepole pine progeny trials were planted in spring 1964 at Elchies, Morayshire and at Broxa, Allerston Forest, Yorkshire. Beech progeny trials were established at Arundel, Sussex and at Alice Holt.

Other Work

Numerous enquiries covering all aspects of tree-breeding work, but, in particular, vegetative propagation and management of seed sources, were received from the Forestry Commission, the Scottish Tree Seed Association and the Forest Tree Seed Association of England and Wales and various outside sources.

Forester R. T. Wheeler assisted with the development of the Pakawa Savall (Forestry Commission pattern) safety harness for tree climbing, illustrated in our Plates. This will be fully described in the 1965 revision of Forest Record No. 39, *Collection of Cones from Standing Trees,* now in the press.

An interesting device for weighing individual seeds, illustrated in our Plates, has been developed by Forester A. S. Gardiner after Duffield, J. W. (A Simple Device for Weight-Sorting Seeds, *Forest Science* 6, (4), 1960).

FOREST PATHOLOGY

By D. H. PHILLIPS

Death and Decay Caused by Fomes annosus (Fr.) Cooke

The testing of chemical stump treatments was continued, and sodium nitrite, the most generally successful of the materials examined, was introduced into three Conservancies. The results of this large-scale trial, and of clearance of sodium nitrite under the Pesticides Safety Precautions Scheme, are awaited before it is recommended that this chemical should be used generally in the forest in place of creosote.

Work has also continued on biological control of *F. annosus* in pine by inoculation with the competing fungus *Peniophora gigantea.* A large-scale user trial with *P. gigantea* has in general given very satisfactory results. The fungus has been issued for use in the field mainly as a culture on malt agar in plastic disposable petri dishes. If this method of control is to be extended to all pine areas in this country, it may well be necessary to use some other form of inoculum that is more convenient to produce, distribute, and store until required. Work on this problem has only just begun. Work has also begun on the screening of fungi that may be used similarly in the biological control of *F. annosus* in Sitka spruce.

A study of the control of *F. annosus* in the new crop has been made on sites on which pines have been killed by the fungus, and the affected crop felled and replanted. In the course of this work it became apparent that in some of these sites, difficulties were being experienced in re-establishment. A preliminary ecological study was made, and from this it appeared that many factors might be involved. The young trees were subjected not only to a risk of heavy losses through attack by fungi and insects remaining from the previous crop, but also to growing conditions in some ways poorer than those in the first rotation. It seemed possible that cold air from the surface of the surrounding crop was draining into the felled areas, which thus became artificial frost hollows. The ground cover of heavy grass, litter and chopped brash insulated the mineral soil, and decreased normal heat exchange, and so further reduced the temperatures encountered by the sensitive Corsican pines that formed the bulk of the new crop. A study of temperature and other factors that may be concerned is being carried out.

Stem Crack

A preliminary investigation into stem crack in *Abies grandis* in the South of England showed that in 17 sites examined an average of 15% of the trees showed external signs of cracking. The proportions affected ranged from 1–49%, but only 5 sites had more than 15% showing crack. Detailed examination of the trees at the worst affected site showed that internal cracks, not visible at the surface, were present only in trees with external scars. Cracks did not extend very far radially. All the major cracks recorded had been initiated in the two drought years of 1955 and 1959. There was some evidence to suggest that the length of cracks decreased with increasing nominal specific gravity of the wood. A fuller study of stem crack is now being undertaken in collaboration with the Forest Products Research Laboratory, Princes Risborough.

Group Dying of Conifers (Rhizina undulata Fr. ex Fr., syn. R. inflata (Schäff.) Quél.)

The observational stand at Muirburnhead, Dumfries-shire, where group development in Sitka spruce followed fires lit in 1955, was again examined, and was almost completely windblown, a consequence of the gaps created by the groups. One group remained, and *Rhizina undulata* was still active in it eight years after colonisation of the fire site.

No appreciable damage was found among conifers in their third year on ground on which *R. undulata* had colonised sites of fires made in clearing the ground for planting, and the fungus appeared to have died out.

Top Dying of Norway Spruce

Further evidence linking this disorder with oceanic winter conditions was found in an investigation into a small outbreak in the Kielder district of Northumberland. It appears that as Norway spruce approaches the pole stage, its growth becomes liable to considerable reduction in seasons following some climatic occurrence associated with mild winters, and that where opening up in or near the crop then causes sufficiently increased air circulation near the time of this growth reduction, top dying may follow.

Bacterial Canker of Poplar Caused by Aplanobacterium populi Ridé

Fifty-eight recently-introduced poplar clones were screened for canker susceptibility by inoculation, and a long-term resistance test of clones, of silvicultural promise, provisionally considered to be canker-resistant was started with an initial batch of 15 clones.

An investigation into the causes of apparent variations in the resistance of individual clones was commenced, and is described in Part III (p. 151). In the course of this work it was discovered that the tunnels of cambium-boring agromyzid larvae appeared to provide the bacterium with a means of spread in the tree, and that extensive infection could result in this way. Preliminary experiments were set up to examine the possibility that strains of the bacterium may vary in pathogenicity. The results suggested that this might be so, though they were not conclusive, and further, more detailed work is needed.

Elm Disease (Ceratocystis ulmi (Buism.) Moreau, syn. Ceratostomella ulmi (Schw.) Moreau.)

Six elm clones from trees bred and tested for resistance in Holland, and 12 from British elms, selected for good timber production or for amenity value, were inoculated in a test bed established in 1962. The clones from Holland, and one British clone from a tree similar to Huntingdon elm, appeared very resistant, and several other clones, including a Huntingdon elm, seemed to be fairly resistant. Clones of Dutch and Wheatley elm were very susceptible.

Damping-off and Grey Mould in Nurseries

Trials on seed and soil treatments to reduce losses through damping-off were laid down at ten nurseries in various parts of the country. The results are in process of analysis. At Maelor, Flintshire, an experiment was laid down to test the effect of certain soil and overhead spray treatments on the incidence of Grey mould (*Botrytis cinerea* Fr.) on Sitka spruce seedlings. *B. cinerea* did not appear in the plots, however.

Effects of Winter Cold

Much damage to trees occurred during the long and very cold winter of 1962–3, though many of the effects of the weather did not become fully apparent for many months. Most of the queries on this kind of damage were therefore made in the summer of 1963, reaching their peak in July.

Among the conifers, worst affected were the cypresses and their allies, particularly the Monterey cypress (*Cupressus macrocarpa*), which was perhaps more severely affected than Lawson cypress (*Chamaecyparis lawsoniana*) or Western red cedar (*Thuja plicata*). In many instances, half-grown, vigorous trees of these, and other cypresses less commonly grown, were completely killed, or so badly damaged that there was little hope of their recovery. When affected trees were not killed outright, the severity of the damage was nearly always greater on the north-east and east sides. This was so on trees with only a small amount of brown foliage, and on others on which the remaining green foliage was confined to a narrow strip on the south-west or west side. These symptom patterns point to the importance of the dessicating effect of the very cold easterly and north-easterly winds.

On *Sequoias*, the symptoms were more general, suggesting overall damage to the tree, without the directional effect seen on the cypresses, and *Sequoia sempervirens* was usually more affected than *Sequoiadendron giganteum*.

Damage on other non-deciduous conifers was variable. Little was recorded on spruces (*Picea* spp.) or *Tsuga*, while on pines many cases of needle browning were noted, but it appeared likely that the affected trees would recover. This browning was reported on Scots, Corsican, Lodgepole, and even Mountain pines. In places, young Douglas fir (*Pseudotsuga taxifolia*) was severely damaged or killed, and young plants of Silver fir (*Abies* spp., particularly *A. procera*) were badly affected in some areas.

Less information is available on winter cold damage to broadleaved trees, though widespread injury certainly occurred, especially to unhealthy trees and to those in unfavourable situations. Severe frost crack and sap bleeding occurred in walnut, and dieback was noted in beech, ash, oak and other trees. Also in the case of oak, the tips of nursery transplants were badly affected where they had projected above the snow cover.

Stem cracks appeared in poplars, and trees sometimes died, while in some cases wilting of leaves and twigs took place as late as mid-June. Indeed, in broadleaved trees in general, injury to bark and cambium and other cold damage to stems was often not evident until the middle or almost the end of the growing season, when wilting of foliage was often the first symptom observed. Investigation then often revealed extensive damage at the bases of the stems of the trees concerned. In some areas, such cases gave rise to alarming reports of mysterious blights devastating trees.

Striking injury of this kind was seen on Southern beech (*Nothofagus procera*), particularly on lower valley slopes, and to lime and plane in built-up areas, probably because temperature fluctuations in such situations are greater than in more open spaces. The *Nothofagus* injury is shown in Plate 16.

In the generally milder winter of 1963–4, injury to trees occurred in cold spells, and in February and March of 1964 some cases of damage were reported, mainly on Scots, Corsican and Lodgepole pine in Yorkshire and southern England, but also on nursery plants of Lawson cypress.

Miscellaneous Fungal Diseases and Abnormalities

Many records were made of diseases caused by fungi and other living organisms. The rusts *Melampsora pinitorqua* Rostr. and *Chrysomyxa abietis* Unger gave rise to epidemics. *M. pinitorqua* (a form of *M. tremulae* Tul.) occurred on Scots pine, mainly in Sussex and Kent, but was recorded as far afield as King's Lynn, Norfolk, and in Warwickshire. Most reports were received between July 10 and August 31, but some continued to come in until early October. In some cases quite severe damage was done to the shoots of young pines when aspen (the most important alternate host of the fungus) was present as a weed in the plantations.

Chrysomyxa abietis affected Norway spruce. Most of the specimens received came from East and South Scotland and Northern England, but this rust was also seen in South Wales and South-west England. In contrast the related rust *C. rhododendri* (also on Norway spruce) was recorded only once, in North Scotland.

Death of young cones of Lodgepole pine was reported from Scotland in the autumn of 1963, while abnormal vegetative growth from the distal ends of larch cones was reported in July from South Wales and North-west and South-east England. These abnormalities were considered to be the result of inadequate fertilisation.

Publications

Results of work so far done on extraction damage, blue stain in pine, the chemical control of Needle blight (*Didymascella thujina* (Dur.) Maire) of *Thuja*, and of a canker of pines associated with *Crumenula sororia* Karst. were prepared for publication. The report on *Thuja* Needle blight appears in Part III below (p. 141).

General

Advisory work continued to occupy a large part of the time of the Section, and 279 enquiries were received, 119 being from Commission forests and 160 from elsewhere. Where possible, field visits were made as a result of the queries, but in practice it was possible to visit only a small proportion of the sites.

FOREST ENTOMOLOGY

By D. BEVAN

Pine Looper Moth (Bupalus piniarius)

Warning of imminent infestation at Cannock Chase Forest in Staffordshire was given in last year's Research Report. The pupal counts upon which the forecast was based were followed by egg counts in July, and these confirmed the presence of a population of pest proportions. The highest compartment mean egg count per tree was over 6,000, and the highest individual tree count in excess of 24,000. 1,374 acres were found to be immediately threatened and were therefore aerially sprayed with 1 lb. of D.D.T. emulsion/acre on the two days August 27 and 28. Very successful control was obtained.

The opportunity was taken during this operation to look for side-effects of the insecticide upon wild-life. The Nature Conservancy, the spraying firm and the Forestry Commission co-operated in this work, and samples of soil, birds and insects were taken for analysis before and after chemical application. The results of these investigations are not yet available.

The 1963/64 pupal survey for the country included 48 units, the majority of which showed little or no change in the looper population. However, the private estate of Innes, Morayshire, holds a highest compartment mean of 16·8 pupae per sq. yard, which is a five-fold increase from last year and the greatest density recorded in the survey. Tentsmuir Forest in Fife continues to report a highest compartment mean of 14·8 pupae per sq. yard, this being the third successive year in which this order of population has appeared.

Grey Larch Tortrix Moth, Semasia diniana

This insect is a well-known alpine pest and although common in this country has nowhere before caused extensive damage. The first outbreak of the larch form was recorded during the year, when about one hundred acres were completely defoliated. Recovery was good and the trees were reclothed with leaves by July/August.

Larch Sawfly, Anoplonyx destructor

Populations of this sawfly were at a low level throughout the country with the exception of Taybank in Perthshire, where defoliation was heavy, and in Craigvinean, also in Perthshire, where slight needle-loss was reported.

Epidemiological studies continue at Mortimer Forest in Shropshire, and investigations into increment loss at Drumtochty Forest, Kincardineshire.

Douglas Fir Seed Wasp, Megastigmus spermotrophus

The study of population changes from year to year in Douglas fir stands distributed throughout the country continues. Data from cone samples collected from individual trees is being supplemented by the establishment of long-term seed-trapping experiments in six seed stands, in collaboration with Silviculturist (South). These are designed to give information about the availability of seed for natural regeneration as well as being a useful method of assessing the general level of infestation by the seed wasp and the extent of parasitization of this pest.

Illustrations of a radiographic technique for examining seeds appear in Plate 13.

No progress was made with the problem of control because of the scarcity of cones on sites suitable for experimentation.

Pine Weevil, Hylobius abietis

Two new experiments on dipping treatments for planting stock have been laid down. One is to compare the phytotoxicity of the common oil-based formulations of D.D.T. and B.H.C. with new formulations which are water-based and therefore expected to be less phytotoxic. The other is to test the effectiveness of the new formulations against the weevil. As in previous experiments, complete dipping is included as this could provide valuable protection against *Hylastes* beetles, as well as against the weevil, if proved non-phytotoxic.

Enquiries

There have been 100 enquiries from Forestry Commission and 80 from private sources.

MAMMALS AND BIRDS

By JUDITH J. ROWE

Control of the Grey Squirrel

Investigations of methods of grey squirrel control are carried out jointly with the Infestation Control Laboratory (Land Pests Branch) of the Ministry of Agriculture, Fisheries and Food.

Poisoning trials with warfarin-treated baits were continued in Scotland. Comparison was made of maize and wheat as vehicles for the poison. While maize can be as effective as wheat it is more difficult to treat with warfarin and squirrels take only the germ, discarding the endosperm. Although differential uptake of warfarin by the germ and the endosperm results in a lower concentration of warfarin in the rejected portion it is felt that this represents a potential hazard to small mammals and possibly to other animals. The entire wheat grain is usually consumed and it is more easily treated with warfarin: on these grounds wheat is preferred as a poison bait. Investigations are also being made of different methods of presenting the poison in order to further increase the selectivity of the technique for squirrels. Hoppers attached to trees and on the ground are under trial.

Protection of a vulnerable crop by cage-trapping in and around it just prior to the damage period (May to July) has now apparently been achieved for three successive years in a non-isolated woodland. The last trial consisted of three trapping operations. A capture/mark/release trapping was carried out in early March, eight weeks before the capture/kill protection trapping at the beginning of May. Only two individuals *not* previously captured were caught in the second operation and these were at trap sites on the edges of the trapping area. This suggests that there is little movement into or from the area if the population is not disturbed during this period. The third trapping was carried out in July and it was found that recolonisation had occurred, although no damage had been sustained.

Field and Bank Voles

Outbreaks of damage by the field-vole, *Microtus agrestis*, have been controlled by the use of warfarin in pinhead oatmeal at a density of about 50 baiting points per acre. Further trials to determine the minimum number of baiting points per acre required and the application of the technique to damage by the bank-vole, *Clethrionomys glareolus*, will be made when suitable experimental sites are found.

Deer Biology

Investigations of various aspects of deer biology have been continued. No entirely satisfactory drug or method of delivery has yet been developed to supersede the practice of netting-up to capture deer.

Nursery: Protection against Birds and Mice

A satisfactory method of treating up to 40 lbs. of seed uniformly by hand with seed dressings has been developed. Trials of thiram formulations and of an anthraquinone preparation, Morkit, were made using rates of application of the order of 15% W/W. Too few birds were present on the nurseries at which trials were made to give a comparison of the repellancy of the dressings. It was found, however, that germination was significantly poorer on all plots treated with anthraquinone. The species used were Corsican and Scots pine, *Pinus radiata* and Norway spruce. There is some indication that Scots pine is more susceptible to the use of dressings than the larger seeded pine species. Trials of two Latex stickers made at the same time showed that both could be used equally easily to apply the dressing to the seed: there was no indication that either interfered with germination.

Damage by the wood-mouse, *Apodemus sylvaticus*, occurred on one of the seed-dressing experiments. The seed-dressings did not deter the mice from taking seed or seedlings. Half-inch mesh netting which has been used to cover control plots reduced the amount of damage significantly but did not entirely prevent the mice from attacking the plots. Use of break-back traps and erection of a mouse-nettting surround to the experiment controlled the outbreak.

Chemical Repellents in the Forest

Tests were made of longevity and phytotoxicity to Scots pine, Norway spruce, Douglas fir and Japanese larch of ten adhesive compounds suitable for use as stickers for chemical repellents. Seven of these were latex formulations, one a cellulose gum, and two were preparations of zinc ammonium alginate. The only phytotoxic effect observed was browning of small patches of needles of Norway spruce following treatment with alginate prepared by a method involving the emission of excess free ammonia. The gum and alginates did not persist for longer than one month: the latex treatments were all present in moderate amounts (75% of foliage covered) at the end of three months.

Trials of various chemical repellents have shown that Arikal, Cunitex and Arasan 42–S will repel deer, but for short periods, four to eight weeks only. Further trials are being made of these compounds with and without stickers against deer, hares, blackgame and capercailzie.

A systemic insecticide which can be applied by soil injection has been developed as a rabbit/hare repellent in the U.S.A. and is under trial.

Electric Fencing

Trials of electric fencing are being carried out in the New Forest against fallow deer. It is apparent that electric fencing cannot be effective against deer on deep-ploughed or uneven ground where it is impossible to drop the lower wire sufficiently to prevent deer crawling under it.

Predation of Broadleaved Seed

Lack of mast precluded investigation of the importance of predation by small mammals, birds and squirrels during the period of seed fall in selected tree stands. The trials did suggest that a certain amount of predation occurs before the seed falls, since a few damaged seeds were collected in funnels. Plate 3 shows the equipment used.

Questionnaires

The annual questionnaire on red and grey squirrels for the year ending September 1963 showed that grey squirrels were still low in numbers and had done comparatively little damage over the country as a whole. The first report was made of grey squirrel damage to Commission plantations in Scotland: a light attack on beech. Red squirrel populations were also reported as being generally lower than last year, but there was little alteration in their distribution.

The annual deer questionnaire showed that there appeared to have been little change in the distribution of deer species generally, apart from roe deer slightly increasing their range in southern England.

PLANNING AND ECONOMICS

By D. R. JOHNSTON

Although notes on the routine duties of the Planning and Economics Branch are no longer included in this report there are several aspects of Soil Survey and Mensuration which have a research content. These are discussed below.

Mensuration

The research content of the Section's work has been mainly concerned with investigating the effects of different initial spacings and of different thinning treatments.

Two experiments have been started with transplants to determine whether it is possible to obtain any useful information from miniature forest crops on the effects of spacing and thinning.

Work has continued on the weekly assessment of the Douglas fir replicated thinning experiment at Alice Holt, and information is accumulating on the detailed reaction of both individual trees and stands to thinnings of different type and intensity.

Permanent sample plots continue to be thinned and remeasured by the Section's field parties at the rate of about 250 per annum. Of the present total of about 800 permanent sample plots, 34% are used as assessment plots in thinning experiments, 12% in spacing experiments and 6% in race and provenance trials. The remainder do not form part of an experiment but 19% can be used to compare the growth of different species on the same site and 4% provide information on the growth and development of mixtures and underplanting. All the plots are made use of for the preparation of yield tables, etc., together with information from Thinning Yield Plots and Management Indicator Stands.

Soil Surveys for Working Plans

At the beginning of the year covered by this *Report*, the soil survey of the New Forest, Hampshire, covering 21,000 acres, was completed. Information was obtained for the calculation of the relative profitabilities of the various species on the range of sites present. The extent and nature of the drainage problem of the heavy clay soils was demonstrated. Areas of open heathland suitable from the soils point of view for enclosure within the Statutory obligations were suggested.

In the early part of the year a soil survey of Wareham Forest, Dorset (9,000 acres), was carried out. Very poor growth of pine stands was related to poor drainage accentuating the infertile nature of the Bagshot Sands.

A soil survey of Clocaenog Forest, Denbighshire, is nearing completion. The aim has been to shed light on the causes of windthrow which is becoming increasingly important in many forests as stands reach a susceptible height. It has been found that windthrow is confined to impeded clay soils (derived from glacial drift) and to shallow peat overlying clay. Root systems are restricted to 9 to 18 inches depth in undrained soils. An extensive programme of deep

(3 feet) drainage is now commencing in these impeded soils, which cover about 55% of the total area of 17,500 acres at Clocaenog.

A similar type of survey is to be undertaken in the near future at Newcastleton Forest, Roxburghshire, where similar windthrow problems occur.

Research into relationships between tree growth and site conditions was carried out at Kershope Forest, Cumberland and Thetford Forest, East Anglia. At Kershope the best expression of site quality for predicting the growth of spruces on the 'Border type' of land was ground vegetation. At Thetford no correlation existed between soil conditions and production of Scots and Corsican pines. Indeed, growth of these species at Thetford on a wide range of soils was remarkably uniform. Yield Class 160 for Corsican pine and 120 for Scots pine means that at 35 years (the age of crop studied) the volume production of Corsican is 150% of that of Scots pine.

WORK STUDY

By J. W. L. ZEHETMAYR

Assignments

Two assignments listed last year, those on forest maintenance problems in North-east England and North Wales Conservancies, were completed. The present assignments are:

North Scotland. On Scottish pulpwood production, based on South Strome Forest in Wester Ross, but work has now been extended to several forests. A District Officer was trained during the year to run a training programme for pulpwood production and was launched on the series of courses described later.

East England. Thetford Chase in East Anglia—Work on mechanisation of pitprop production and in connection with the sawmill and chipboard factory at Thetford. Some work on weeding, brashing and pruning.

North-west England. Thornthwaite Forest in Cumberland—Work on production operations, mainly conversion and trials of long peeled pitwood.

South Scotland. Early in 1964 intensive trials were begun in Newcastleton Forest in Roxburghshire to study the effect on production costs of the length of pulpwood billets.

New Forest, Hampshire. A general assignment tackling felling of both hardwoods and conifers, extraction and transport and also forest maintenance operations, brashing and weeding to date.

Silvicultural Operations

From the North Wales assignment now completed there has emerged a pattern of how the Work Study investigation into subjects such as brashing or weeding may be conducted most economically. The pattern runs like this:—

1st Season Investigate the job intensively by method studies and time studies. Decide on the most serviceable methods and produce a draft table of standard times.

2nd Season Test the methods and standard times over a fairly wide area, the Work Study Officer visiting forests as necessary to introduce the scheme, initiate training, investigate difficulties and make additional studies.
Evolve a comprehensive scheme of standard times.

3rd Stage Distribute down to District Officer with recommendations for application, and pass training over to Conservancy staff.

4th Stage After a reasonable interval, publish results when sufficient experience justifies it.

The operations at present nearing the end of this process are brashing and weeding, while draining and pruning are somewhat less advanced.

Production Operations

The year has been devoted to two main themes: firstly following up the general principles stated last year, of minimal conversion at stump, followed by extraction and mechanical loading onto long distance transport, and secondly work on particular machines or on products for specific industries. The industries were:—

Scottish Pulp and Paper Mills (Wiggins Teape and Co. Ltd.), Fort William.

While most work was on production technique for the specification previously evolved, and on the training aspects, the emphasis is now moving to the method of payment for logs and pulpwood for estimating their relative volumes in order to facilitate forecasting. Work on transport moved slowly because the revision in the specified length from 12 to 10 feet, though it hardly affected work in the forest, did upset preliminary conclusions on the most suitable type of road vehicle.

Pulpwood in the Borders

Early results from the trials at Newcastleton Forest show that 7½– and 10–foot lengths cut in the wood are substantially cheaper to produce than 4–foot billets cut at roadside. The 7½–foots are slightly more expensive than the 10–foot mainly because the cross-sectional area becomes limiting on sledges, or for winch loads, and reduces the volume per load.

Wood Chipboard Factory at Thetford (Airscrew Weyroc, Ltd.)

Production methods have evolved very easily from the established method of working at Thetford Chase, so the main work has been on payment and estimation of volume. A feature here has been the decision, on Work Study's recommendation, that all chipwood will be cut with chainsaws on two piece-rate scales, paid according to whether the saw is owned by the worker or the Forestry Commission.

Peeled Pitprops

A detailed appraisal of the methods in use at Brandon Depot, Thetford Chase, culminated in the recommendation, which was accepted, to install a mobile Cambio peeling machine. This machine will be used to peel suitable poles brought in direct from the forest—about 500,000 hoppus feet over bark per annum—and lay down windrows of long peeled pitwood to season; saw-benches can then cut the seasoned material to order. A design for a new saw-bench to eliminate the heavy lifting and manual sorting of products is the next stage in this project.

The Cambio peeling machine was received from Sweden early in 1964, and the first trials gave good promise of achieving the production target, while halving the cost of peeling compared with current methods.

Long Peeled Pitwood

Investigations at Thornthwaite Forest in Cumberland have sought to ascertain the best production methods and the costs, for 7–foot and 10–foot peeled lengths with a top diameter of 2½ ins. to 5 ins. The method developed involved cross-cutting in the wood, extraction by horse sledge and peeling on a Cundey barking machine fitted with feed wheels; this proved successful. A stacked measure rule was adopted so that volume can be used for payment, in preference to weight. The maximum seasoning attainable is the aim, in order to reduce transport costs.

Attempts to accelerate seasoning by covering stacks with plastic were unsuccessful; site—an open ride as compared with "within the stand"—proved the most important factor in rate of seasoning.

Forest Trials of Machines

A considerable extension of the number of machines under test has been a feature of the year. All the machines are intended to fit into existing or planned logging operations. They are briefly listed with the main points arising:—

Light Tracked Tractors

Two are under trial on peat in the Border Forests. They can go where no wheeled tractor can. Much work is needed to integrate them into the system, and to provide them with the correct extraction equipment.

Double Drum Winches

About twenty Norwegian Isachsen double drum winches are now working in Britain but a lot remains to be done on training and improving performance.

Where the thinning yield is about 400 hoppus feet per acre, a trained operator should be capable of extracting about 600 hoppus feet per day, provided careful attention is paid to rack lay-out, and loads are properly prepared. The Crychan winch developed by the Forestry Commission in South Wales is considered a satisfactory light alternative under specified conditions. A hydraulic double drum winch was tested but failed to match the performance of the Isachsen or the Crychan.

Single Drum Winch

A single drum winch mounted on a Fordson tractor was shown to be superior to a single drum winch on wheels, and indeed little use can be seen for the latter type of winch, since the loss in mobility is not compensated for by lower running costs.

Loading Cranes

Methods of using hydraulic timber cranes were studied for a number of products and several types of hoist. It would appear that the larger two-ton type, which with a hydraulic grapple winch costs about £1,200, is likely to take over from the smaller one-ton type with sling or hook loading, as is already happening in Sweden. While only one such crane was in use in the Forest Year 1963, on an articulated vehicle hauling 10- and 12-foot pulpwood in North Scotland, by early 1964 the following were starting trials:—

(i) Lorry-mounted for short distance log transport at Thetford;

(ii) Tractor-mounted to feed the Cambio peeling machine in Brandon Depot, Thetford;

(iii) Tractor-mounted to load pulpwood and logs on to lorry, and/or to extract pulpwood from rackside.

The mechanisation of most loading is now possible, but great care is needed to integrate it with the transport system. Studies have been made of the 'break-even' distance for lorry-mounted cranes, annual out-turn required for various types, etc. Ten tons per day should be the minimum acceptable with the big loaders, and fifty tons a day is feasible. The most intractable problem is concerned with the short lengths hauled long distances by return-load general transport—short pulpwood and pitprops are typical—where hand loading seems inevitable for many years.

Dissemination of Information

Quarterly Report and Work Study Papers

Four *Work Study Reports* have been prepared and circulated to Forestry Commission staff. They have contained both progress reports on various aspects of the work in hand and eight separate papers on items nearing completion:—

Tools and Equipment: Tools for Weeding and Cleaning;
*Tractor extraction with Thetford Tongs.

Results of a complete Work Study: *Brashing of spruce, pine and larch;
*Weeding in plantations.

Technical data: Outputs from team working of pulpwood;
*Movement costs of various extraction methods.

Work Study practice: The concept of standard time;
Checking a piece-rate scheme.

Items marked * are being prepared for general publication.

National Productivity Year: The Work Study Section assisted substantially in the organisation of seven one- or two-day open meetings, demonstrating tools and methods, often with actual operations in progress. Over a thousand people attended these demonstrations.

The Section's collection of over 150 hand tools and related equipment was catalogued and put on exhibition at several of these meetings.

The Section played a part in the meeting on "Efficiency in Forestry" organised at Oxford by the Society of Foresters of Great Britain.

Pulpwood Production Training Scheme

A special training team was set up under the guidance of Work Study in the area due to supply the Fort William Mill in Western Scotland. The types of training being given are:—

(*a*) *Logging Course for Junior Foresters.* Three weeks on practical felling, horse work, double drum winch, and organisation of work, piece-rates, etc.

(*b*) *Short Logging Course for Senior Foresters.* One-week courses run in conjunction with (*c*), all aspects of the works being demonstrated and discussed.

(*c*) *Pulpwood runs at selected forests.* Based on Isachsen winch extraction, up to eight men are given a chainsaw course and then produce logs and pulpwood under intensive supervision for a number of weeks. The compartment worked is carefully described and costed, outputs per man/day being calculated. In these trials a notable improvement in output over the period is generally observed.

These runs should also serve to introduce and test the recommended piece rate and measurement systems being evolved by the Work Study team.

UTILISATION DEVELOPMENT

By B. W. HOLTAM

Properties of Home-grown Timber

The joint programme of research, with the Forest Products Research Laboratory of the Department of Scientific and Industrial Research, into the properties of home-grown timbers, entered its sixth year.

The comparison of the properties of the timbers of Japanese and European larches was completed, and a report is being prepared for publication by Forest Products Research Laboratory. The results indicate that there is very little difference between the two species; the main points of difference are that Japanese larch is less liable to degrade during seasoning, and is slightly less resistant to indentation than European larch.

The examination of the properties of Norway spruce has continued, and all consignments of sample logs have been delivered to the Laboratory.

Although the sampling and testing of the timber and pulping properties of Lodgepole pine was reported in last year's *Report* to have been completed, it was decided that further information on this species was required; consequently further sampling is taking place and consignments of logs from the Irish Republic and from Allerston Forest have been sent to Forest Products Research Laboratory.

Work began on a comparison of the yield and properties of timber sawn from pruned and unpruned logs. Sample logs of Norway spruce were supplied from Tintern and Dean forests, Douglas fir from Inverliever and Dean forests, and European larch from Dean forest only.

Other work undertaken at the Laboratory included an assessment of the strength and bending properties of ash from eight sites in different parts of Britain and experiments in the control of blue stain in pine logs; an examination of the properties of the timber from a consignment of home-grown Weymouth pine (*Pinus strobus*) was also undertaken.

Home-grown Timber for Plywood Manufacture

Logs of oak, Scots pine and Douglas fir were delivered to the Forest Products Research Laboratory for peeling trials to assess the usefulness of these species for the manufacture of sheathing grades of plywood, for which there is an expanding market.

Sawn Hardwoods: Markets

The survey, referred to in last year's report, into uses for home-grown sawn hardwoods in England and Wales, was completed. A report was prepared and circulated to the Home-Grown Timber Advisory Committee and to the Marketing Liaison Committees.

Wood Flakes as Litter for Cattle and Poultry

This project, which was started in 1961, was practically completed and a final report based on information obtained from litter trials with beef and dairy cattle and poultry, has been prepared for publication. The use of these flakes is shown in Plate 14.

The manurial value of spent flake litter, which had been used as bedding for beef cattle, was assessed by applying it to a hay crop at a rate of 15 tons per acre. The yields of the treated plots were 80% higher than those of the untreated controls and were slightly higher than those of plots treated with straw litter manure. The long-term effect of applying wood flake manure to crops is now being studied by the National Agricultural Advisory Service at Reading.

Fence Post Trials

The annual assessments of treated and untreated round fence posts were made for the sixth successive year in Scotland and the fifth successive year in England and Wales. Only 50% of the untreated softwood and 28% of the untreated hardwood posts remain sound. No creosoted post has failed so far.

Predrier Development Project

A simple low-cost kiln has been designed by Forest Products Research Laboratory for the purpose of reducing the moisture content of green timber to 20%–25% of its dry weight. The kiln has heat and draught control only; no attempt is made to adjust the humidity of the circulating air. A kiln of this design is being built at the Laboratory to study the technical aspects of its operation, and the Forestry Commission has made tentative arrangements for the commercial trials of two kilns of similar design in the yards of home-grown timber merchants, one in England and one in Scotland.

MACHINERY RESEARCH

By R. G. SHAW

Due to the rapidly rising output of British forests the emphasis in machinery development is turning towards timber handling and loading equipment.

Tractors continue to play a leading part in every aspect of forestry work and new developments are permanently under review. Hydrostatic transmission, which is now available on commercial tractors, is on trial, but it is unlikely to make much impact on forestry until the price differential compared with mechanical transmission is reduced. The first tractor designed in Britain specifically for forestry use has reached the pilot production stage.

There is a marked trend towards four-wheel drive tractors which can now be fitted with tyres of very large section, to take the place of tracked tractors for most conditions.

The use of powered loaders for all types of timber transport vehicles is rapidly increasing and there are now several types on the market.

Trailers with power driven wheels have been under examination for a long time. Early attempts in this direction were disappointing owing to the difficulty in transmitting power by shaft through the acute angles imposed when a tractor with trailer is on full lock. There are indications that improved universal joints and, possibly, hydraulic transmission, will shortly eliminate these difficulties.

Ploughs are under constant development, particularly for the digging of open drainage ditches of increasing depth. The practical limit has been reached at a depth of 30 to 36 inches, beyond which the rear-mounted digger becomes the only satisfactory current solution, though continuous-acting types are under examination, particularly for drain clearing.

Power saws continue to improve and it is worthy of note that the one-man power saws now in use in British forests have doubled in cutting speed and halved in weight within the last decade.

Timber extraction by winch now calls for double drum winches using a return drum to eliminate the need to haul out the main cable by hand. Ranges up to 150 yards are being worked very satisfactorily by this method and various means of extending this range are being examined.

Bark peeling is now carried out mainly at the various factories producing timber products where large machines can be installed, peeling at very low cost. There is still however a demand for mobile peelers and research continues to be directed towards finding a machine which can fill this role at minimum cost.

The light pendulum saw bench imported from France last year has given good results and a tractor-mounted pendulum saw is being designed.

DESIGN AND ANALYSIS OF EXPERIMENTS

By J. N. R. JEFFERS

General Functions

The functions of the Statistics Section have continued to be those of providing advice on the design and analysis of experiments and surveys to other Sections of the Research Branch and to the Forestry Commission in general; of undertaking the analysis and interpretation of numerical information; and of carrying out research into the application of statistical methods and techniques of electronic digital computing to problems of forest research and management. In the year under review, the first full year in which the Section has had the use of its own electronic digital computer, an International Computers and Tabulators Sirius, there has necessarily been some re-organisation of the Section so as to make better use of the greatly improved computing facilities now available. One new machine operater has been recruited, to help with the task of transferring the data on to punched paper tape, but there have been no other changes in the number of staff employed. The functions and deployment of the staff have however been greatly changed by the introduction of the computer, and, although careful preparations had been made in the training of staff at all levels, there were necessarily some delays in finding the most efficient methods of operating the computer to give a maximum of productive time.

Special courses on computer programming and computer applications have been run for Research Branch and other Forestry Commission staff at all levels. As a result, there has been a general increase in the amount of work sent to the Section for analysis, and much of this work arises from new applications of statistical and computing techniques.

The training value of the work of the Section is high because of the wide variety of statistical methods used, and a number of students have been employed during vacations, or during the industrial training periods in Diploma of Technology courses. Some of these students came from overseas, and were sponsored by the Commonwealth Forestry Institute, others from the Ministry of Aviation, and one was paid by the Forestry Commission.

As in other years, advisory work has been undertaken for a number of overseas forest departments, and for other organisations and research stations interested in forest problems. It should, however, be stressed that much has been gained by the Forestry Commission Research Branch from this co-operation with other organisations. Not only does much valuable information become available in this way, but the opportunity to test statistical techniques over a wider range of species and conditions helps to refine the techniques themselves, and thereby improves their value within the research work of the Forestry Commission.

Design of Experiments and Surveys

Advice on the design of experiments and surveys remains an important function of the Section, and designs have been provided for more than 140 investigations throughout the year. No very marked changes in the types of investigations for which designs were required was observed during the year, most of the work taking the form of the consolidation of the many new types of designs and experiments introduced in previous years.

The greatest increase in the advisory work of the Section, however, has been in connection with the application of operational research techniques to problems of forestry research and management. Partly as a result of the greater computing facilities available, and partly as a result of the educational activities of the Section, the scope of operational research techniques has become apparent over a wide range of management problems, and a number of special projects have been undertaken to determine the value of such techniques in forest management. Perhaps the greatest value has come from the investigations associated with the construction of the pulp mill at Fort William by Scottish Pulp and Paper Mills (Wiggins Teape and Co. Ltd.). Special studies of extraction and conversion problems in providing material for pulping have been undertaken by mathematical techniques, and the final conversion and felling schedules were determined in this way. Similar investigations into the staffing of the Forestry Commission, both for industrial workers and for the supervisory grades, were also carried out mathematically for the Commission's Establishment Section. Similarly, studies of the growing and allocation of nursery stocks, have indicated that greater efficiencies could be achieved by mathematical methods of programming and allocation, and a long-term study of this application has been started.

Analysis of Experiments and Surveys

The demand for the analysis and interpretation of numerical data has continued to increase, and more than 15,000 separate analyses were completed in the year under review. Only a quarter of these analyses were routine analyses of the intermediate assessments of long-term experiments, the remainder being special analyses of more complex research and management problems.

Applications of methods of multivariate analysis have continued to be of special interest to the Section, and have led to investigation into the taxonomy of species of plants of importance in practical forestry, investigations of economic factors in forest estates, complements and work loads of forest staff, and the factors affecting the growth of trees on a wide range of sites.

Computer Programming

Since the Sirius computer was directly compatible with the Pegasus computer that was used previously for most of the computational work of the Section, very little reprogramming was involved in the change from one computer to another, and the Section was therefore able to continue with an ambitious programme of computer programming. More than 200 programmes are now available for various aspects of statistical work of value in forest research and management, and a publication describing these programmes and the algorithms used in them is in preparation. The control desk of the Sirius computer is shown in Plate 15.

The staff of the Statistics Section of the East Malling Research Station of the Kent Incorporated Society for Promoting Experiments in Horticulture, have co-operated with the staff of the Section in the task of writing computer programmes for the wide variety of statistical methods of value in the analysis of data from experiments on perennial crops, and the great value of this co-operation is acknowledged.

International Union of Forest Research Organisations

In addition to the First Conference of the Advisory Group of Forest Statisticians, held at Alice Holt in September 1963, and mentioned earlier in this *Report*, work on behalf of the Advisory Group has been undertaken by members of the Section. Most of this work has been in connection with the collection and distribution of information on electronic digital computers and their application to problems of forest research and management, this being the special responsibility of the Statistician as a member of the Advisory Group.

Statistics Section Papers

Six Statistics Section Papers were produced for internal circulation during the year, with the following titles:

63 J. N. R. JEFFERS. Use of fertilisers in Forestry Commission forests.

64 A. J. STEVENS. Estimation of the density per acre of a forest by the method of distance sampling.

65 R. LINES and R. HOWELL. The use of flags to estimate the relative exposure of trial plantations.

66 J. N. R. JEFFERS et al. Discussion of factor analysis.

67 J. N. R. JEFFERS and H. G. M. DOWDEN. Moisture content and specific gravity of fresh-felled conifers: weighted tree means.

Number 65 above has been published as Forest Record No. 51. (H.M.S.O. 3s. 0d.); any enquiries regarding the remainder should be directed to the author.

PHOTOGRAPHY

By I. A. ANDERSON

This has largely been a year of consolidation. Another photographer has joined the staff but this really only enables us to keep pace with increased requests for services. No new work is being undertaken and little progress made with the backlog of material for the central collection.

Photographic Collection

17,001 slides were loaned for lecture purposes. There is no lessening of demand for this service which started 10 years ago with the loan of 652 slides in the first year. Though the emphasis is now clearly on the use of colour, not only for lectures, but for straightforward record photography and, to some extent, for use in publications, we continue to maintain a collection of Monochrome prints. 1,218 of these were used, mainly for exhibition and for publication.

A start was made on 'streamlining' the Monochrome collection. This has been a very useful exercise. Storage space is limited, and the original intention was simply to reduce the bulk of old photographs, unless they had historical value, so that additions could be balanced against withdrawals. It has also shown however, that there are considerable gaps in coverage and that the classification and indexing can be improved.

Films

360 loans of films were made. Little progress was made with our own film programme and, in view of other demands on the Section's time, it seems unlikely that we will do more than produce a short training film or two in the coming year.

General Services

Demands for map reproduction increased considerably. This process is expensive in material and labour, and we have been looking for alternative methods and materials. Several have been tried, and one at least looks promising. If acceptable, it should achieve a substantial reduction in costs.

Duplication of colour transparencies continued, not only for use within the Forestry Commission, but for universities, institutes, and forestry organisations at home and abroad.

PUBLICATIONS AND LIBRARY

H. L. EDLIN

Publications

A steady flow of material came forward for publication and was dealt with on well-established lines. Thirteen new publications were issued through Her Majesty's Stationery Office:

Reports

Forty-third Annual Report of the Forestry Commissioners, 1962 (H.C.175. Session 1962–63) (6s. 6d.)

Report on Forest Research for the year ended March 1962 (13s. 0d.)

Bulletins:

No. 35. Pruning Conifers for the Production of Quality Timber, by D. W. Henman (6s. 6d.)

No. 36. Mycorrhizal Associations and Calluna Heathland Afforestation, by W. R. C. Handley, Commonwealth Forestry Institute, Oxford. (8s. 0d.)

Forest Records:

No. 48. The Dropmore Pinetum, by A. F. Mitchell (5s. 6d.)

No. 49. The Development of Douglas Fir Plantations in Relation to Site Conditions, by W. R. Day, Commonwealth Forestry Institute, Oxford. (1s. 0d.)

No. 50. Wind-loosening of Young Trees on Upland Heaths, by M. V. Edwards, J. Atterson and R. S. Howell (2s. 0d.)

No. 51. The Use of Flags to Estimate the Relative Exposure of Trial Plantations, by R. Lines and R. S. Howell. (3s. 0d.)

Booklet:

No. 9. Felling and Converting Thinnings by Hand, by R. E. Crowther and I. Toulmin-Rothe (2s. 6d.)

Leaflet:

No. 47. Birds and Woodlands, by B. Campbell (2s. 0d.)

Guides:

North Yorkshire Forests, edited by H. L. Edlin (7s. 6d.)

Forests of North East Scotland, edited by H. L. Edlin (5s. 0d.)

Short Guide to the Dean Forest and Wye Valley (9d.)

A joint publication with the Department of Scientific and Industrial Research was also issued through H.M. Stationery Office, as Special Report No. 18 of the Forest Products Research Laboratory, entitled "*Bark Form and Wood Figure in Home-grown Birch*". Its authors were R. J. Newall of the Forest Products Research Laboratory and A. S. Gardiner of the Forestry Commission.

In addition, twenty-one existing publications were revised and re-issued. The full list of available publications (H.M.S.O. Sectional List No. 31) was also revised; copies will gladly be sent to any enquirer on request.

The usual exchange arrangements were maintained with research stations and forestry departments, mainly overseas, and much valuable information was gained in return.

Library

The Library was placed under the control of the Publications Officer on May 1 1963, and in October Mr. R. G. Harris was appointed as Assistant Librarian.

Library routine changes little from year to year, but there have been a few shifts in emphasis. Rapid advances in many of the fields of knowledge which a modern forestry library must serve, have made it more important than ever to procure and circulate books and papers as soon as possible after they appear. Where necessary, we have revised our procedures to this end.

Bound Books

Steps have been taken to fill gaps in our special collections, which comprise:

(a) Textbooks on British forestry and British forests, ancient and modern.

(b) Textbooks, published within Britain, on trees and their cultivation within the British Isles, including both native and introduced kinds.

(c) British forestry periodicals, from the earliest available issue onwards.

We have also expanded our textbook coverage of timber utilisation, in line with the growing importance of harvesting and marketing wood, and many kinds of wood products, to the Forestry Commission's economy.

These two operations together explain an exceptionally large number of accessions to our 'bound books' section, totalling 311 volumes as against 149 in the previous year.

There has also been a welcome donation of some 90 volumes, previously loaned to the Library by the late Mr. James Macdonald, formerly Deputy Director General of the Forestry Commission. Our thanks are due to Mrs. Macdonald for this generous gift.

There are now 4,260 volumes in our Library catalogue. Three-quarters of these are held in the Library itself, and the remaining quarter are on permanent loan to specialised sections.

Periodicals and Series

The volume of forestry literature issued as journals, reports and occasional papers by research stations and forestry societies continues to expand. A recent check showed that we receive and register 450 of these series. They vary in frequency from weekly issues to annual reports.

Loans, Borrowings and Translations

1,100 loans were made from our main library and periodical shelves; of this number, some 90% were to members of the Commission's staff, and 10% to outside enquirers. In addition we borrowed, on behalf of enquirers, 450 items from other libraries, whose help is greatly valued.

Increasing use—to the extent of 150 copies within six months, is being made of the Photo-copying Service of the National Lending Library at Boston Spa. This has the great advantage of providing, at low cost, copies of papers for permanent retention, rather than loan items that have to be returned within a few weeks.

Forty translations of articles in foreign language periodicals were made; and their existence was notified to other libraries through the Commonwealth Translation Exchange Scheme.

Reference Cards

Additional references have been added to the Library card index at a steady rate, and we are now keeping pace with the current appearance of major papers in world forestry literature. The following statement shows how the main classifications stand.

Class of Card	*Added during the Year*	*Total at End of Year*
Author	2,200	25,000
Subject	3,000	52,000
Geographical	300	9,300
Total	5,500	86,300

As at least two cards, and sometimes many more, must be made out for each paper referenced, these figures represent the addition of some 2,000 papers, to give a total of some 35,000 individual items indexed. The choice of suitable items to be included, out of the far greater number published annually, is a major task for the Librarian.

The Commonwealth Forestry Bureau, with its publication *Forestry Abstracts* and associated card references, continues to be our major and highly valued source of classified information on what has been published. But we also cast our own net over periodicals and books on subjects bearing indirectly on forestry, to pick up 'fringe' items.

PART II

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

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RESEARCH ON SCOTTISH FOREST AND NURSERY SOILS

By H. G. MILLER and R. C. MACKENZIE,
The Macaulay Institute for Soil Research, Aberdeen

Following the transfer of Dr. W. O. Binns to the Forestry Commission Research Station at Alice Holt Lodge and the resignation of Dr. J. Keay, work carried out during the year has been on the same broad lines as in the previous two years and no new projects have been started. The recent appointment of Dr. J. B. Craig has now brought the staff up to its previous strength.

Nitrogen Nutrition

In co-operation with the Forestry Commission the Institute is now running five experiments to investigate various aspects of nitrogen fertilisation in the forest. These are situated on coastal sand dunes at Culbin Forest, Morayshire, on a peaty podzol with thin iron pan at Broxa, Allerston Forest, Yorkshire, on a peaty podzol without an iron pan but with an indurated layer at Inshriach Forest, Inverness-shire, and two experiments on a relatively infertile river terrace at Alltcailleach Forest, Aberdeenshire.

It was already known that ten to twenty-year-old Corsican pine on the poorer areas of Culbin sand would respond to added nitrogen (*Rep. For. Res., For. Comm. Lond.* 1960) and an experiment to test rates and forms of nitrogen application was laid out in 1961. The nitrogen, as 'Nitrochalk', was applied at four rates of 45, 90, 135 and 180 lb of nitrogen per acre, some plots receiving only a single application in 1961 whereas others had the first three rates repeated annually. In 1962 the two highest annual treatments (135 lb. and 90 lb.) had increased the annual height increment by about 75 per cent and in 1963 the corresponding increase was over 120 per cent in relation to the untreated control plots. Even after three years' application, however, the lowest annual treatment (45 lb.) was still producing a smaller growth rate than the highest single treatment (180 lb.) applied three years earlier, which in 1963 produced height increments about 90 per cent greater than the control plots. The pattern for diameter increment of the 1958 internodes is very similar though the increases are somewhat greater; in 1963 the highest annual dressing increased diameter increment by about 160 per cent over the control plots and the highest single dressing produced a corresponding increase of over 100 per cent. Despite the high rates of nitrogen applied, the foliage nitrogen level has not yet risen above 1·2 per cent, and the curves of height increment and diameter increment over foliage nitrogen content in the previous autumn show that the point of maximum response has not yet been reached. This is particularly true of height increment, the curve for which is still climbing steeply even at the highest foliage nitrogen levels. In the case of diameter increment of the 1958 internode the curve is showing a tendency to flatten off at the higher nitrogen levels, but this may not be the case for internodes nearer the growing tip. Both measures of increment show a closer relationship to the foliage nitrogen content in the October of the *previous* growing season than to that in the October of the *same* season. Included in the same experiment are treatments with a crude vermiculite-ammonia complex (1·64 per cent nitrogen) at 1·15 cwt nitrogen per acre, and an exfoliated vermiculite-ammonia complex (0·755 per cent nitrogen) at 0·555 cwt nitrogen per acre, in the hope that one or both of these might prove to act as a fairly long-lasting form of nitrogenous fertiliser. To date these treatments have produced no appreciable improvement in either the foliage nitrogen content or in the tree growth over the control plots.

At Broxa in Allerston Forest an experiment was laid out in 1962 in which nitrogen, as 'Nitrochalk', was applied to a mixed crop of Japanese larch and Sitka spruce, planted in 1954, at 61, 122, 183 and 244 lb. of nitrogen per acre. These treatments were applied both once and annually. The diameter growth of the Sitka spruce shows a relationship to the foliage nitrogen content in the previous autumn, but height growth shows little obvious relationship, possibly because many leading shoots have been physically damaged. Preliminary evidence tentatively suggests that rate of increment with increased foliage nitrogen content is flattening out at about 1·1 per cent nitrogen. Some plots, however, were given an additional treatment of 71 lb. of phosphorus per acre and in these height growth, though not the diameter growth, of the spruce is markedly superior to any other plot, suggesting that at nitrogen applications above 120 lb per acre phosphorus is becoming the limiting nutritional factor to spruce growth on this soil. In the case of Japanese larch, a relationship between growth and foliage nitrogen content in the previous autumn exists only for those plots that were treated once at the beginning of the experiment. In the case of those plots receiving an annual treatment, there is a closer relationship with the foliage nitrogen content at the end of the same season: this is probably explained by the deciduous habit of larch. In both the repeated and non-repeated series of treatments the higher levels of nitrogen application have depressed growth. Present evidence suggests that maximum growth of the larch is occurring at a foliage nitrogen level of about 2·9 to 3·0 per cent, and at levels above about 3·5 per cent growth is less than in the untreated control plots.

In the same year a similar experiment was laid out in a ten-to-twenty-year-old Scots pine crop at Inshriach Forest. The nitrogen rates are the same as at Broxa, except that the highest rate has not been repeated annually. The application of 183 lb. of nitrogen per acre in both years of the experiment has raised the foliage nitrogen content to about 1·8 per cent, as against the 1·2 per cent of the untreated control plots; at this level, however, the trees show signs of yellowing. A full growth assessment has still to be carried out, but visible responses in colour and height growth after the 1963 season were not marked, though plots that received phosphorus and potassium in addition to nitrogen appear to be healthier than those plots treated with nitrogen alone.

Investigations into the nitrogen nutrition of mature Scots pine at Alltcailleach Forest have continued (*Rep. For. Res., For. Comm. Lond.* 1963) and these two experiments are due for a full assessment in 1965.

Drainage of Peat

The experiment at Lon Mor, Inchnacardoch Forest (*Rep. For. Res., For. Comm. Lond.* 1963), has continued, and in co-operation with the Forestry Commission a start has been made on sampling peat from Flanders Moss, Loch Ard Forest, Stirlingshire, where a large-scale drainage experiment is to be laid out. The developing of membrane-covered electrodes for oxygen assessments is continuing, but as yet these have not been tested in the field.

In pot experiments in the greenhouse the effect of keeping peat flooded on the growth of Lodgepole pine, Scots pine and Sitka spruce has been examined. The growth of all these species was reduced by the flooding, and the needles of the pines, in particular Lodgepole pine, tended to turn brown and to be shed. Sitka spruce, on the other hand, retained all its needles despite the flooding, though the newest needles eventually became rather yellow and showed occasional purple discolouration. Flooding resulted in a marked decrease in the chlorophyll concentration in the needles of all species, this reduction being greatest in the case of Lodgepole pine and least in the case of Sitka spruce. In all species flooding almost halved the nitrogen concentration in the needles, significantly reduced the magnesium, sulphur and copper concentrations, and increased the iron concentration. In both pines, particularly Lodgepole pine, the phosphorus/iron ratio in the needles was greatly reduced by flooding, but this was almost unaffected in the spruce.

Forest Nurseries

Regular analysis of the soil from the four Long-term Fertility Experiments in Scottish Nurseries (*Rep. For. Res., For. Comm. Lond.* 1957) has continued in rotation. In December 1963 samples were taken from the experiment at Newton Nursery in Morayshire, and these are at present being analysed. Results so far obtained show that neither hopwaste nor greencropping has significantly changed the level of organic matter in the soil. A highly significant increase in the acetic-soluble phosphate content in those plots treated with hopwaste, over all other treatments, has again been found (*Rep. For. Res., For. Comm. Lond.* 1962) but until the analysis has been completed it is not possible to say whether there has been a loss of phosphorus from the soil, other than through the plants, as indicated by the previous results.

PUBLICATION

KEAY, J. 1964., Nutrient deficiencies in conifers, *Scottish Forestry* 18 (1).

Summary

As in recent years the emphasis of the work conducted at the Macaulay Institute has been on the nutritional requirements in the forest, in particular for nitrogen. On the nitrogen-deficient sands at Culbin Forest in Morayshire nitrogen applications have raised the foliage nitrogen level of young Corsican pine as high as 1·2 per cent, with a large resulting increase in growth rate. It would seem, however, that both these could be further increased with heavier nitrogen dressings. On heathland soils at Broxa, Allerston Forest in Yorkshire, and at Inshriach Forest in Inverness-shire, the response to nitrogen is less marked and somewhat more complex than at Culbin. At Broxa the growth of young Sitka spruce appears to become limited by phosphorus deficiency at the higher

rates of nitrogen application, and the growth of Japanese larch is actively depressed by the heavier nitrogen dressings. At Inshriach young Scots pine treated with heavy rates of nitrogen are showing signs of yellowing. Investigations into the effect of drainage on peat and the resulting tree growth have continued. Pot experiments show that Sitka spruce is more resistant to flooded conditions than Scots pine and Lodgepole pine, and of the pines the Lodgepole is markedly less resistant than the Scots. These differences can be related to the chlorophyll and nutrient levels in the tree foliage. In the nursery the effect of hopwaste in producing a high soil phosphate content has been confirmed, but hopwaste and greencropping are found to have no appreciable effect on the soil organic matter content.

NUTRITION EXPERIMENTS IN FOREST NURSERIES

Potassium Manuring of Sitka Spruce Seedlings

By BLANCHE BENZIAN

Rothamsted Experimental Station, Harpenden, Herts.

In late summer, Sitka spruce seedlings, grown with soluble potassium fertilizers on a leached sandy Wareham soil, often develop typical discolorations associated with K-deficiency. In the presence of a basal dressing of 'Nitro-chalk', superphosphate and kieserite (magnesium sulphate), four rates of KCl were tested either as a *single* dressing before sowing or as a *divided* dressing (half before sowing and half in late June). The single application doubled height and dry matter (with only small differences between rates) (Table 7); divided dressings gave a further increase of 10-20%. By contrast, the single dressings improved seedling colour only slightly, but the divided K applications prevented deficiency symptoms and considerably increased %K in the plants, the high rate trebling it. Although in 1963 seedling growth at Wareham was below average, numbers, which were not affected by treatment, were large (1,640 seedlings/sq. yd.) and total dry matter produced was comparable with long-term averages. Uptake of K (lb/acre) ranged from 4·7 for no-K plots to 32 for plots receiving the high rate divided.

TABLE 7

YIELDS, POTASSIUM-DEFICIENCY SYMPTOMS AND POTASSIUM IN CROP (TOPS+ROOTS) OF ONE-YEAR SITKA SPRUCE SEEDLINGS AT WAREHAM NURSERY IN 1963

(Low rate=mean of 4·5 g and 9 g K/sq. yd.)
(High rate=mean of 13·5 g and 18 g K/sq. yd.)

	Height (in.)	Dry matter (mg/plant)	Visual colour score*	K in dry matter (%)	K in crop	
					lb/acre	% recovery
K applied						
None	0·7	85	6	0·31	4·7	—
All in March						
Low rate	1·4	160	5	0·44	11·9	18
High rate	1·6	167	4	0·48	14·2	8
Half in March, half in June						
Low rate	1·7	195	1	0·68	23·6	34
High rate	1·7	196	0	0·92	32·2	20

*0=no discoloration

In a small trial, seedlings with severe K-deficiency symptoms grown on plots manured with 9 g K/sq.yd. (as KCl) in March, had their green colour restored by a single September top-dressing of KCl (4·5 g K/sq. yd.); %K in the plants was increased from 0·4 to 1.

Summary

Sitka spruce seedlings grown on a leached sandy Wareham soil developed characteristic K-deficiency symptoms, even at high rates of KCl given as a single dressing before sowing. Where half the quantity of KCl had been withheld until June, the K-concentration in the plants was greatly increased and the seedlings were almost completely symptom-free. The extra benefit on height was, however, small.

In another trial a top-dressing of KCl applied as late as September restored the green colour to K-deficient Sitka spruce seedlings.

Note—This contribution has previously appeared in the *Annual Report of the Rothamsted Experimental Station for* 1963.

PATHOLOGY EXPERIMENTS ON SITKA SPRUCE SEEDLINGS

By G. A. SALT
Rothamsted Experimental Station, Harpenden, Herts.

Although sowing was delayed until the last week of April, moist warm weather after sowing resulted in emergence of seedlings within 4 instead of the usual 6 to 8 weeks. Percentage emergence and numbers of survivors were greater than usual in most nurseries and treating the seed with 50% thiram dust or methoxy ethyl mercury chloride had no beneficial effect, in contrast to the previous year when emergence was slower and seed dressings were significantly beneficial.

Survival and Growth of Seedlings in Different Nursery Soils

Experiments in which formalin and chloropicrin were applied to the same plots for 4 consecutive years were concluded. Except for Bagley Wood where chloropicrin caused damage in some plots, there was no evidence that the beneficial effect of these partial sterilants declined with successive applications.

Table 8

NUMBERS OF SEEDLINGS IN 5 NURSERY SOILS

TREATMENTS		FINAL STAND		SEEDLINGS PER SQ. YARD			
SOIL	SEED	Kennington K.90	Kennington Ex. KE88	Bagley B.52	Ringwood R.87	Wareham W.95	MEAN
Untreated	Red lead	825	1289	1508	1243	998	1173
	Mercury	684	1274	1373	1196	817	1069
Residual formalin	Red lead	1031	1240	1534	1175	1134	1223
	Mercury	819	1319	1454	1271	848	1142
Formalin	Red lead	883	1233	1343	1400	900	1152
	Mercury	875	1170	1420	1363	841	1134
Chloropicrin	Red lead	797	1258	1224	1336	1044	1132
	Mercury	940	1210	1208	1436	864	1132
MEAN	Red lead	884	1255	1402	1289	1019	1170
	Mercury	829	1243	1364	1317	842	1119

Formalin and chloropicrin increased the number of survivors at Ringwood (Table 8) where in untreated soil an average of 162 seedlings per sq. yd. died soon after emergence; they had no effect on numbers in other nurseries where there was little or no damping-off. At Wareham, many seedlings were lost in untreated and treated plots because the radicles failed to penetrate the soil, but there was no indication that this was due to damage by pathogens.

Table 9

GROWTH OF SEEDLINGS IN 5 NURSERY SOILS

SOIL TREATMENTS	HEIGHTS IN INCHES					
	Kennington K.90	Kennington Ex. KE88	Bagley B.52	Ringwood R.87	Wareham W.95	MEAN
Untreated	2·022	2·298	2·083	0·620	2·085	1·822
Residual formalin	2·239	2·080	2·068	0·725	2·163	1·855
Formalin	2·292	2·346	2·600	1·487	1·803	2·106
Chloropicrin	2·773	2·316	1·926	1·981	2·665	2·332
Mean	2·332	2·260	2·169	1·203	2·179	

Seedlings were severely stunted in untreated soil at Ringwood, but at Kennington they grew almost as well as at Wareham (Table 9). Growth was increased more by chloropicrin than by formalin, except at Bagley Wood where chloropicrin caused damage. Growth responses to residues of formalin applied in December 1961 were small at Old Kennington, Ringwood and Wareham, and absent at Kennington Extension and Bagley Wood.

Sowing Date Experiments

Sowing date experiments on the same sites at Kennington and Ringwood during the last 4 years showed that early sowing in March or April always yielded the tallest seedlings and usually the largest number of survivors. Successive sowings made from late April until early July resulted in smaller seedlings but numbers showed no consistent trends. In some years (Kennington 1960, Ringwood 1962, 1963) few seedlings survived from sowings in May and/

Table 10

SOWING DATE EXPERIMENTS

NUMBER OF SURVIVORS PER SQ. YARD

RINGWOOD (R.92)

Sowing date	3 April	26 April	15 May	6 June	27 June
Soil untreated	973	966	585	799	1000
Formalin treated	1260	1350	950	974	1017

KENNINGTON (K.95)

Sowing date	3 April	22 April	20 May	6 June	27 June
Soil untreated	977	1258	1437	1319	1287
Formalin treated	1321	1412	1595	1468	1425

Table 11

EFFECT OF SOIL TREATMENTS ON NUMBERS AND HEIGHTS OF SEEDLINGS

	TREATMENTS (Amounts per sq. yd.)					
	Untreated	Formalin[1] (250 ml.)	Metham-sodium[1] (550 ml.)	"Dazomet"[2] (29g of 85W dust)	"Quintozene"[2] (112·5g of 20% dust)	"Nabam"[1] (2·0g of Dithane A.40)
KENNINGTON (K.94)						
Third count 25 June Seedlings per sq. yd.	989	998	635	951	817	1009
Final stand .	1154	1402	1232	1292	962	1227
Mean height	2·36	2·87	2·03	3·02	1·80	2·51
RINGWOOD (R.91)						
Third count 11 July	1346	1481	1486	1478	1328	1486
Final stand	951	1377	1431	1362	1141	1146
Mean height	0·42	1·81	1·92	1·97	0·57	0·87

[1]Applied as a drench in 4 to 5 litres of water.
[2]Applied dry and forked in.

or June, whereas in other years large numbers survived from all sowings, as at Kennington in 1963. Soil treatment with formalin often increased numbers and always increased growth more at Ringwood than at Kennington (Table 10). Where there was poor emergence from mid-season sowings in unsterilized soil, there were usually similar failures in formalin-treated plots, indicating that dry soil conditions and not soil pathogens may have been the main cause.

Effect of Different Soil Chemicals on Seedling Survival and Growth

Results of applying chemical treatments to the same plots to obtain cumulative effects agree closely with those obtained last year. At Ringwood, numbers of seedlings were increased more by the partial sterilants formalin, metham-sodium and 'Dazomet' than by the fungicides 'Nabam' and 'Quintozene' (Table 11). Growth was very poor in untreated soil and was substantially increased only by partial sterilants. At Kennington, seedlings grew unusually well in untreated soil, so that growth responses to formalin and 'Dazomet' were not so noticeable, and metham-sodium and 'Quintozene' both depressed growth. More seedlings survived than at Ringwood and numbers were increased only by formalin. Good growth in unsterilized soil at Kennington was associated with repeated dressings of ammonium sulphate fertilizer which decreased soil pH from about 5·5 to 4·5 (in 0·01M calcium chloride). In an adjacent experiment, comparable seedlings grown in unsterilized soil grew to 2·14 inches where ammonium sulphate had decreased soil pH to 4·9, and to only 1·27 inches where 'Nitro-chalk' had maintained the pH at 5·5. It is also possible that Sitka spruce may prefer ammonium to nitrate nitrogen.

Seed Quality

Poor quality seed with a germination of 21%, sown at 27g, and normal seed with 67% germination sown at 7g to give 1,800 viable seeds per square yard, both produced similar stands on untreated soils and on those treated with formalin, 'Dazomet' and metham-sodium. Thiram seed dressing had no effect on the emergence of either type of seed.

Experiments with Transplants: Nematode Investigations

Seedlings grown in untreated and formalin treated seed beds in 1962 were transplanted into untreated and formalin treated beds in 1963.

Growth in transplant beds was independent of the initial sizes and hence the vigour of seedlings derived from the differently treated seed beds (Table 12). The results confirm those obtained last year and show that stunting can affect seedlings at all stages of growth, and is independent of damage caused by damping-off fungi soon after emergence. Formalin treatment of transplant beds greatly decreased numbers of the parasitic nematode *Hoplolaimus uniformis* which was abundant on seedlings from untreated soil at Ringwood. Numbers of this nematode did not increase significantly where seedlings from untreated soil were transplanted into formalin-treated transplant beds (Table 12). Either nematodes were lost during the time between lifting in November and transplanting in spring or, if they survived, their development in partially sterilized soil was inhibited. The latter suggestion is possible because similar growth responses were obtained in experiments where seedlings lifted from seed beds were transplanted immediately into adjacent transplant beds, but no information on nematodes was recorded in these experiments.

Table 12

EFFECT ON GROWTH OF FORMALIN APPLIED TO SEEDBED AND TRANSPLANT BED

TREATMENTS Seedbed	Transplant bed	GROWTH IN INCHES Seedbed	Transplant bed	Final height of 1 + 1 tree	No. nematodes per 100g soil*
KENNINGTON. K.97					
—	—	2·45	6·63	9·08	Not sampled
Formalin	—	2·86	6·38	9·24	
—	Formalin	2·37	7·51	9·88	
Formalin	Formalin	3·16	7·74	10·90	
Mean effect of formalin		+0·60	+1·12		
RINGWOOD. R.94					
—	—	1·94	0·51	2·45	2440
Formalin	—	2·80	0·20	3·00	2030
—	Formalin	1·91	3·84	5·75	90
Formalin	Formalin	2·90	3·78	6·68	55
Mean effect of formalin		+0·93	+3·46		

*Numbers of individuals of Hoplolaimus uniformis in 100g moist soil washed from roots of 1 + 1 trees in Nov. 1963.

Although it seems likely that parasitic nematodes at Ringwood cause stunting, the results are inconclusive because formalin affects so many other processes in soil, some of which may also affect growth. At Kennington, growth responses to formalin were also recorded, although the magnitude of these responses was less than at Ringwood. Growth in Kennington soil, unlike that at Ringwood, is stimulated by soil acidification, and so the causes of stunting are probably different from those at Ringwood.

Soil Fungi and Nematodes

Root residues from previous crops were abundant in seedbeds at Ringwood and Wareham at sowing time and were examined for pathogenic fungi. *Cylindrocarpon radicicola* Wr. was the most frequent isolate from residues in untreated soil and occurred on 98% and 66% of root pieces from Ringwood and Wareham respectively. It was decreased by the December application of formalin to 12% and 8% respectively in the two nurseries and was not isolated from root residues treated with 'Dazomet'. A species of *Phoma* (1M1 103000) found on 40% of untreated root residue samples at Ringwood was not isolated from residues treated with 'Dazomet' or formalin nor from untreated residues at Wareham. *Fusarium oxysporum* Schlecht. ex Fr. occurred on 20% of untreated residue samples at Ringwood but on few samples from soil treated with formalin or 'Dazomet'. *Pythium* species were relatively uncommon on root residues and were isolated from only 2 to 4% of samples except those treated with 'Quintozene' (12%). Root residues from soil treated with partial sterilants became colonized by other fungi rarely found on untreated residues. Thus residues from formalin treated soil yielded 42% *Coniothyrium fuckelii* Sacc. (1M1 102941) at Ringwood, and 88% *Penicillium* spp. at Wareham. *Pythium* spp., mainly *P. irregulare* Buism. and *C. radicicola*, were the only two fungi isolated consistently from Sitka spruce seedlings that became diseased after germination on finely chopped root residues mixed with quartz grit. 33% of the seedlings yielded *Pythium* alone, 13% *Cylindrocarpon* alone and 23% both fungi together.

Table 13

ISOLATIONS FROM ROOTS OF SEEDLINGS GROWN IN UNSTERILIZED SOILS. (PER CENT ROOTS).

ORGANISM	RINGWOOD (R.91)		KENNINGTON (K.94)		WAREHAM (W.95).	
	June	Nov.	June	Nov.	June	Nov.
Cylindrocarpon radicicola	85	100	25	55	42	95
Pythium spp. .	20	20	5	0	5	0
Fusarium oxysporum	45	10	15	0	18	0
Fusarium solani	0	0	20	0	2	0
Fusarium sambucinum	0	0	0	0	22	5
Hoplolaimus uniformis . (Number per 100g moist soil)	—	530	—	125	—	20

The most prevalent fungi isolated from Sitka seedlings sampled at random from untreated soils at Ringwood, Kennington and Wareham nurseries soon after emergence in June and again in November are shown in Table 13. Partial sterilants greatly decreased numbers of all these fungi throughout the season, whereas the fungicide 'Nabam' controlled them early in the season only, and 'Quintozene' only decreased the numbers of Fusarium isolates.

Pathogenicity Tests

The survival of Sitka spruce seedlings grown at 20°C in small plastic pots of sterilized quartz grit inoculated with pure cultures of fungi on agar discs was recorded. Each pot was sown with 50 seeds that had been surface-sterilized for 30 minutes in 25% chloros (sodium hypochlorite), watered with distilled water, and fertilized with a nutrient water culture solution (Hoagland), giving a pH of about 6·0.

There were no survivors from any pot inoculated with *Pythium*, including *P. ultimum* Trow. from Kennington, *P. irregulare* Buism. from Ringwood and *P. spinosum* Sawada from Wareham. Whereas all species of *Pythium* killed most seedlings before emergence, the other fungi tested caused most deaths after emergence. The survival of viable seeds in uninoculated controls ranged from 30 to 45% in different tests, compared with only 6% for one isolate of

C. radicicola; 6, 7, 13, 22 and 37% respectively for 5 isolates of *F. oxysporum* from Ringwood; 18% for *Fusarium solani* (Mart.) Sacc. from Kennington and 26% for *Fusarium sambucinum* f.6.Wr. from Ringwood. Four fungi commonly isolated from partially sterilized soils, *Penicillium canescens* Sopp, *Trichodermas viride* Pers. ex Fr. and 2 mycelia sterila (T.97, and T.226) were not pathogenic and had 64, 47, 51 and 36% survivors respectively. Similarly two fungi commonly found on seed, *Rhizopus stolonifera* (Ehrenb. ex. Fr.) Lind, and *Aspergillus niger* van Tieghem., were not pathogenic and had 52 and 58% survivors respectively. The experiments were not continued long enough to detect any growth differences among the survivors.

Summary

Investigations were continued into the causes of stunting and the nature of growth responses to partial sterilization of soil in old forest nurseries. Experiments with transplants indicated that the growth stimulus from partial sterilization operated at all stages of seedling development and was independent of root damage caused by fungi early in the season. Seed bed losses were caused primarily by species of *Pythium* and secondarily by *Cylindrocarpon radicicola* Wr., *Fusarium oxysporum* Schlecht ex Fr. & *Fusarium solani* (Mart.) Sacc. These losses were controlled by soil fungicides and partial sterilants, but only the latter substantially increased growth.

BIOLOGY OF FOREST SOILS: EARTHWORMS

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The methods used to assess the disappearance of oak and beech leaf tissue have now been thoroughly examined (*see Heath, Edwards and Arnold,* 1964). At first, subjective visual estimates were made of the amount of leaf lamina eaten by soil animals, but a photoelectric method has now been evolved. The results from both methods agree quite well, as can be seen from Fig. 3. In general, visual estimates are slightly larger than photometric measurements, except for small leaves having very many small holes in them; photometric measurements of these tend to be larger than visual estimates. A good relationship was found between visual estimates of percentage leaf area eaten, and the percentage remaining of the original sample weight (Fig. 4). Visual or photometric estimates can, therefore, be used as an alternative to estimates by weighing. Where necessary, therefore, progressive decomposition can be studied on the same leaf. Because such a close relationship was found between percentage loss of original weight and percentage disappearance estimated visually, it is concluded that, for oak and beech leaves, most initial decomposition was caused by animal feeding. Had decomposition of leaf lamina been caused by microorganisms

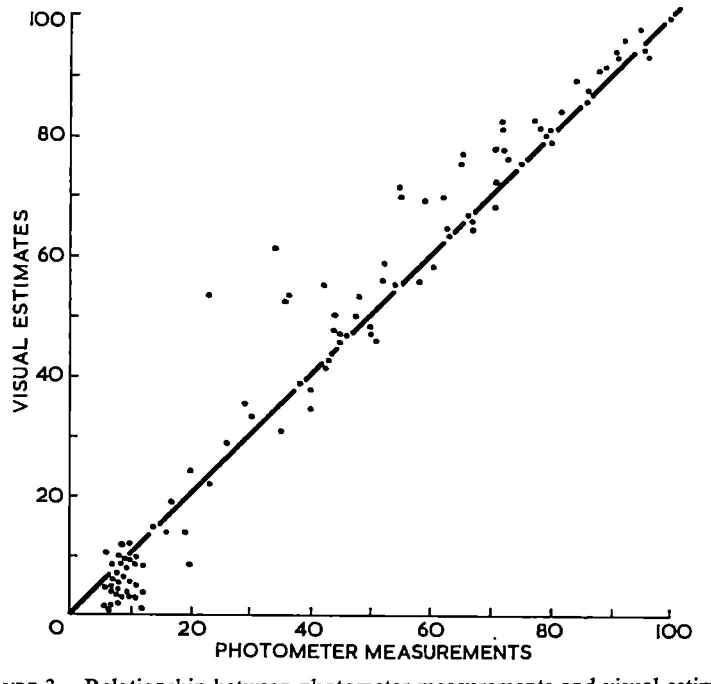

FIGURE 3. Relationship between photometer measurements and visual estimates

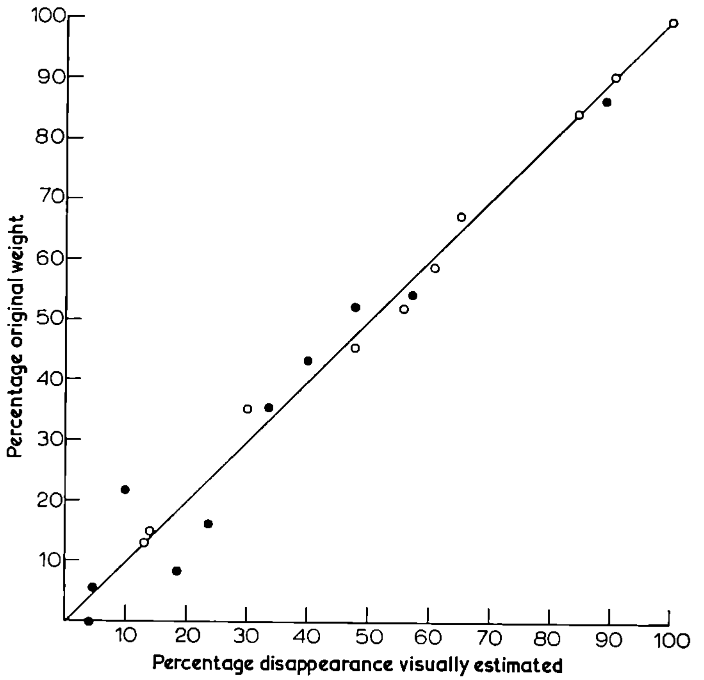

FIGURE 4. Relationship between visual estimates of percentage leaf area eaten and percentage remaining of the original sample weight. Open dot indicates oak; full dot indicates beech.

alone, then the line showing the relationship between weighing and visual estimates would be expected to depart from the 45° slope. It has been previously reported that no significant loss in weight could be detected from intact lamina.

Investigations have continued into the different rates of disappearance of the so-called 'hard and soft' leaves of oak and beech. These descriptions are thought to be synonymous with 'sun and shade' leaves respectively. Leaves of oak and beech were sorted into 'hard and soft' categories at the time of leaf-fall and placed on the soil surface and covered with terylene net as described in last year's report. The severe winter of 1962–63 made it impossible to assess the early stages of disappearance, but from April and September, counts were made to find the percentage number of discs remaining when earthworms were allowed to feed. Figs. 5 and 6 give the result for oak and beech leaves respectively and show that soft leaves were consistently removed more rapidly than hard leaves and that oak was removed more rapidly than beech. The analyses of the samples from the experiment are not yet complete.

Some of the investigations into the factors responsible for changes in the palatability of leaves to soil animals have been reported (Heath and King, 1964). Table 14 shows changes which occur during 44 weeks in the litter layer of some fractions of oak leaves found to be palatable or unpalatable. The most interesting differences are to be seen in the amount of polyphenolic compounds. Total nitrogen decreases, as does 'Lignin' (the insoluble portion after the sample has been treated with 72% W/V H_2SO_4) and the petrol-soluble fraction also decreases during the year. The fact that the palatable leaves were always lower in polyphenol units was thought to indicate that polyphenol concentration *per se* was responsible for differences in palatability, but further investigation of this point suggests more complicated reasons. Fig. 7 shows the results of an experiment where the percentage disappearance of palatable and unpalatable ('soft and hard') oak leaf discs is compared with the decrease in total polyphenols (as measured in arbitrary units). Although the rate of fragmentation increases once the polyphenol content has fallen to 0·5 units (having started at 3·0), polyphenols decrease most rapidly about 8 months before tissues disappear most rapidly, and the unpalatable leaves continue to disappear more slowly even when the polyphenols are the same in both series. One possible explanation of this was discovered by chromatographic analysis of the polyphenol fraction, which indicates that gallic and protocatechuic acids may be less concentrated in palatable than in unpalatable leaves. This point is undergoing further investigation.

TABLE 14

CHEMICAL ANALYSIS OF OAK LEAF DISCS

No. of weeks in litter layer	*Ash %*	*% Total Nitrogen*	*%Petrol Soluble Material*	*50% Methanol Extract*	*Polyphenols*	*'Lignin' %*
UNPALATABLE SERIES:						
4	5·99	1·54	0·85	3·15	4·78	41·3
8		1·27	0·64	2·25	2·73	31·1
12		1·38	1·06	2·82	2·61	35·3
16		1·10	0·47	4·33	1·20	34·8
20		1·29	0·36	2·00	1·64	22·7
24		1·13	0·47	2·62	1·25	23·4
28		1·18	0·22	2·27	0·71	21·1
32		1·11	0·41	3·76	0·82	32·2
36		1·10	0·16	1·52	0·89	17·7
40		1·12	0·23	1·96	0·72	21·7
44		0·55	0·10	1·48	0·76	16·3
PALATABLE SERIES						
4	5·49	1·38	1·58	4·11	3·45	35·2
8		1·89	1·53	3·43	2·15	40·2
12		1·17	1·10	1·99	1·40	31·7
16		1·11	0·76	1·47	1·48	26·5
20		1·40	1·01	2·54	1·44	32·8
24		1·36	0·94	1·60	0·66	26·2
28		1·25	0·49	2·18	0·94	29·3
32		1·08	0·52	2·09	1·09	27·5
36		1·05	0·44	1·60	0·97	23·6
40		1·00	0·27	1·44	0·82	21·8
44		0·67	0·19	0·96	0·73	16·9
REFERENCE SAMPLE OF FRESHLY FALLEN OAK LEAVES:	5·45	1·47	1·48	15·7	2·68	33·7

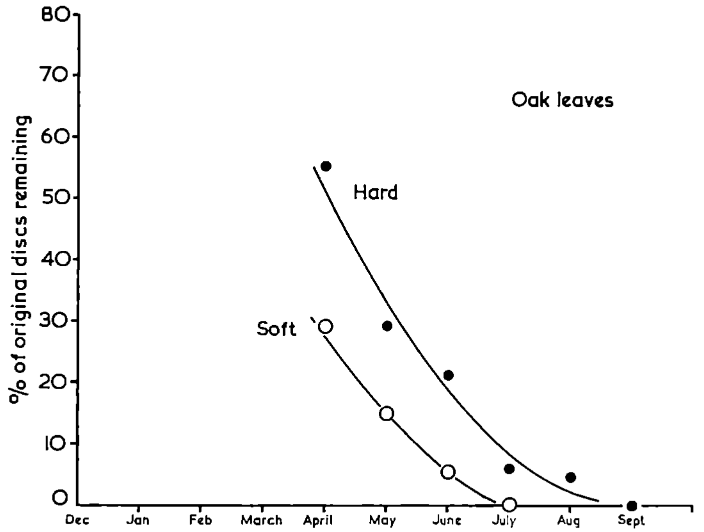

FIGURE 5. Rates of removal of 'hard' and 'soft' oak leaves. N.B. *Remaining* percentages are shown.

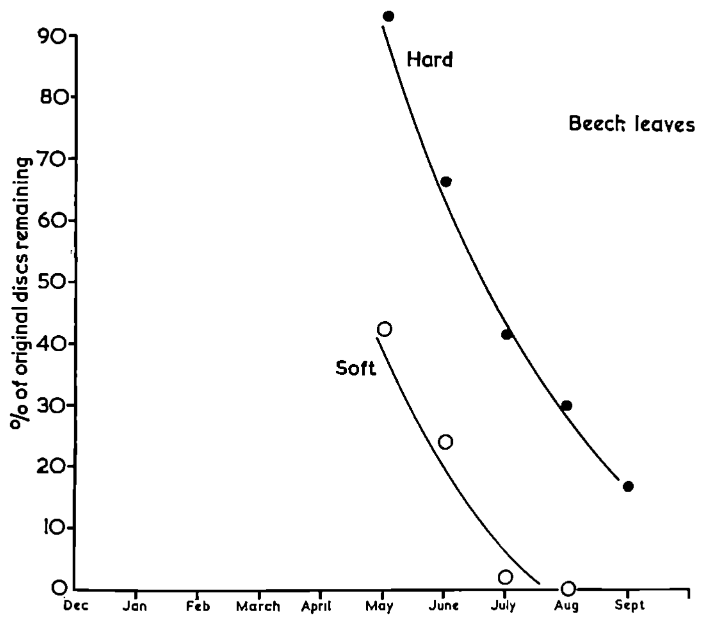

FIGURE 6. Rates of removal of 'hard' and 'soft' beech leaves. N.B. *Remaining* percentages are shown.

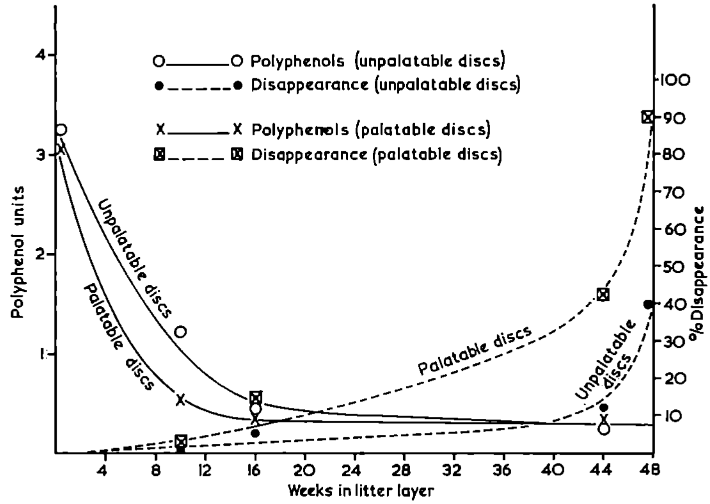

FIGURE 7. Results of an experiment wherein the percentage disappearance of palatable and unpalatable ('soft' and 'hard') oak leaf discs is compared with the decrease in total polyphenols (as measured in arbitrary units).

Summary

Comparisons have been made between the different methods of assessing the rate of disappearance of leaf discs. Investigations into the rates of disappearance of 'hard' and 'soft' leaves have shown that soft leaves consistently disappear more quickly than hard leaves. Of the various factors investigated as being probably responsible for changes in the palatability of leaves total polyphenols seemed to be important; the possibility of gallic and protocatechuic acid being the most important compounds is being further investigated.

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BIOLOGY OF FOREST SOILS: MICROARTHROPODS

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As stated in the 1963 *Report*, this work is becoming increasingly concerned with the wider aspects of litter decomposition, since the microarthropods themselves have such complex associations with the other organisms in their environment. In order to study these relationships we have begun to work on the process of redistribution of the carbon in leaf litter during its decomposition. We are still in the stage of technique development, and this is therefore only briefly outlined.

A growth cabinet was constructed to grow two-year seedlings in natural light, with a closed circuit atmosphere in which carbon dioxide derived from $carbon^{14}$ labelled sodium carbonate was the primary source of carbon dioxide during the shoot and needle development of the seedlings, i.e. May to September. Labelling of the plant material was investigated in July in co-operation with Dr. A. J. Hayes, whose work on the fungi of our litter is reported in his contribution which follows, together with a note on the fractionation of needle and stem material. The development of needles was atypical of Scots pine, due to poor humidity control in the environment, and since work is now in progress to obviate this problem, no detailed account of the growth cabinet technique will be given here.

Litter of these plants was obtained by depriving them of water until they died, and this material is now being used in a pilot experiment at Rannoch. Squares of labelled litter have been substituted for the current natural leaf-fall, and serial collections of the soil animals are being made to measure incorporation of $carbon^{14}$ with the population. Techniques for measurement of the vertical redistribution of organic material in the soil are being developed, as well as an investigation of the respiration of the whole system by measuring labelled carbon output in carbon dioxide.

BIOLOGY OF FOREST SOILS: MYCOLOGY OF SCOTS PINE LITTER

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During the past year, the examination of the microfungi occurring on Scots pine (*Pinus sylvestris* L.) litter was continued. As stated in the previous report, the aims were:—

(1) To determine the fungus flora on leaf and twig litter of Scots pine as it decays.

(2) To define, if possible, the distribution of the fungi in the experimental area.

(3) To elucidate the physiology of these fungi, using a number of pure substrates.

(4) To ascertain the exact role of these fungi in the decomposition of Scots pine litter, and hence determine the precise fate of each substance occurring in the leaf.

Litter was taken from a small defined area of the Black Wood of Rannoch, Perthshire: a dense natural stand of pure Scots pine, 70–80 years old, with very sparse ground flora. Weekly collections of leaf litter from the L, H and F layers and also of twig litter were continued, and these have been plated out direct onto 2% malt agar. A parallel series, previously surface-sterilised, has also been plated out. Surface sterilisation of the needles was effected by shaking them for five minutes with a 0·1% silver nitrate solution in McCartney vials on a reciprocating shaker, followed by a further five minutes in 0·1% sodium chloride solution, and then by shaking for five minutes in sterile distilled water. Much of the work to date has been concerned with the identification of the fungi developing on these plates, and their isolation into pure culture.

Results

Approximately two thousand isolates have been made over the past eighteen months, comprising approximately one hundred and twenty species. 16 of these (12%) are Phycomycetes; 5(4%) are Ascomycetes and the remainder Fungi Imperfecti and Sterile Mycelia. Of these one hundred and twenty species, ninety have been identified, and the remaining thirty await identification. 28(30%) of the species were isolated only once. A complete species list is in the course of preparation, and since this appears to be the first time that any detailed work has been carried out on the microfungi in natural Scots pine woodland in Great Britain, it is hoped to submit this shortly for publication in the *Transactions of the British Mycological Society*. Table 15 shows that, in unsterilised material four species (3% of the total) make up approximately 70% of all isolations. In the surface-sterilised material (Table 16), the picture is quite different, and 11 fungi (9%) make up approximately 70% of the isolations.

Although the individual distributions of these fungi will be described in greater detail later in this report, it is perhaps not out of place to draw certain conclusions at this stage. It may be noted that there was a drastic reduction in the occurrence of *Mucor hiemalis* and also a marked decrease in the frequency of *Penicillium spinulosum*. The incidence of *Phoma humicola*(?) is seen to have doubled, and that of *Verticicladium trifidum* has increased considerably, suggesting perhaps, reduced competition between these species and *Penicillium spinulosum* or *Trichoderma viride*. It is possible, therefore, to distinguish the common, heavily sporing soil saprophytes *Mucor hiemalis*, *Trichoderma viride* and *Penicillium spinulosum* from those species actually growing within the needles.

Table 15

FREQUENCY OF COMMON FUNGI ON UNSTERILISED LITTER

Species	*Percentage of isolations*
Mucor hiemalis	27·3
Penicillium spinulosum	15·4
Phoma humicola(?)	7·2
Trichoderma viride	17·3

Table 16

FREQUENCY OF COMMON FUNGI ON SURFACE STERILISED LITTER

Species	*Percentage of isolations*
Cephalosporium acremonium	2·5
Geotrichum candidum	2·8
Pachybasium hamatum	4·9
Penicillium spinulosum	7·8
Penicillium janthinellum	2·5
Penicillium funiculosum	6·7
Phoma humicola(?)	15·1
Rosellinia aquila	2·3
Stemphylium ilicis	3·5
Trichoderma viride	15·4
Verticicladium trifidum	8·5

Seasonal Distribution

The frequencies of occurrence of seven common litter microfungi on sterilised and on unsterilised litter are shown in figures 8, 9, 10 and 11.

Layer L needles

Mucor hiemalis occurred commonly throughout the sampling period on unsterilised litter, but was removed almost completely by surface sterilisation (Fig. 8). This suggests that this species is very sensitive to the sterilising agent and also that it is present as spores or as superficial mycelium on the needles, rather than as an internal coloniser. This supports the views of Kendrick (1957). *Penicillium spinulosum* occurred regularly on both types of litter, but was less frequently recorded on surface-sterilised litter, suggesting that this species is present partly as spores or superficial mycelium. *Phoma humicola*(?) was isolated regularly from both types of litter, but there was no real difference in the frequency of its occurrence on unsterilised as compared with surface-sterilised litter. It occurred most commonly immediately after needle-fall (October 1962, September 1963) and its incidence then decreased gradually as the fallen needles aged. *Verticicladium trifidum*, the imperfect stage of *Desmazierella acicola*, was completely inhibited on unsterilised litter, either by *Trichoderma viride* or by *Penicillium spinulosum*, but was recorded regularly on surface-sterilised litter towards the end of the experimental period. *Trichoderma viride* was recorded commonly on both types of litter throughout the sampling period. There was a slight reduction in its frequency of isolation on surface-sterilised litter, suggesting that this species also exists partly as spores and surface mycelium and partly as an internal coloniser. Although isolated occasionally from unsterilised litter, *Geotrichum candidum*, *Pachybasium hamatum* and *Penicillium funiculosum* were isolated regularly from surface-sterilised litter only towards the end of the sampling period.

Layer F Needles

Cultural studies on needles from the F layer showed a somewhat different fungus microflora (Fig. 9). As the litter aged, the incidence of *Phoma humicola*(?) decreased considerably, so that this species was now of only minor importance. *Pachybasium hamatum* and *Verticicladium trifidum* both became more common at the end of the experimental period, while *Mucor hiemalis*, *Penicillium spinulosum* and *Trichoderma viride* were all recorded constantly. *Geotrichum candidum* and *Penicillium funiculosum* occurred sporadically throughout the sampling period. *Mucor hiemalis* was again eliminated, and *Penicillium spinulosum* and *Trichoderma viride* were reduced in frequency following surface sterilisation.

Layer H Needles

No attempt was made to sterilise material from the H layer, since the needles were now in small porous fragments which would allow too much penetration by the sterilising agent. The fungus microflora of the H layer seems to be dominated by *Mucor hiemalis*, *Penicillium spinulosum* and *Trichoderma viride*, accompanied by *Mortierella ramanniana* and *Pachybasium hamatum*. *Phoma humicola*(?) is entirely absent from the H layer. (Fig. 10).

Twig litter

The fungus microflora occurring on twig litter is somewhat different from that occurring on leaf litter. (Fig. 11). *Verticicladium trifidum* and *Penicillium funiculosum* are absent both from unsterilised and from surface-sterilised wood, and the dominant microfungi are again *Mucor hiemalis*, *Penicillium spinulosum* and *Trichoderma viride*, accompanied by *Geotrichum candidum*, *Pachybasium hamatum* and *Phoma humicola*(?), the latter mainly at the end of the sampling period.

There was little evidence of any seasonal fluctuation in the numbers of fungi present, save perhaps in *Phoma humicola*(?), which tended to be more common on newly-fallen litter. In general these findings support the conclusions of Kendrick (1957), although there are a number of differences. Kendrick demonstrated a succession of fungi on decaying needle litter of Scots pine similar to that found in the present investigation, a small number of initial colonisers being followed by a larger number of secondary forms. He found that *Pullularia pullulans* and *Fusicoccum bacillare* were of major importance in colonising freshly-fallen needles, and although both these species have been isolated from litter collected on the Rannoch site, they appear to be of very

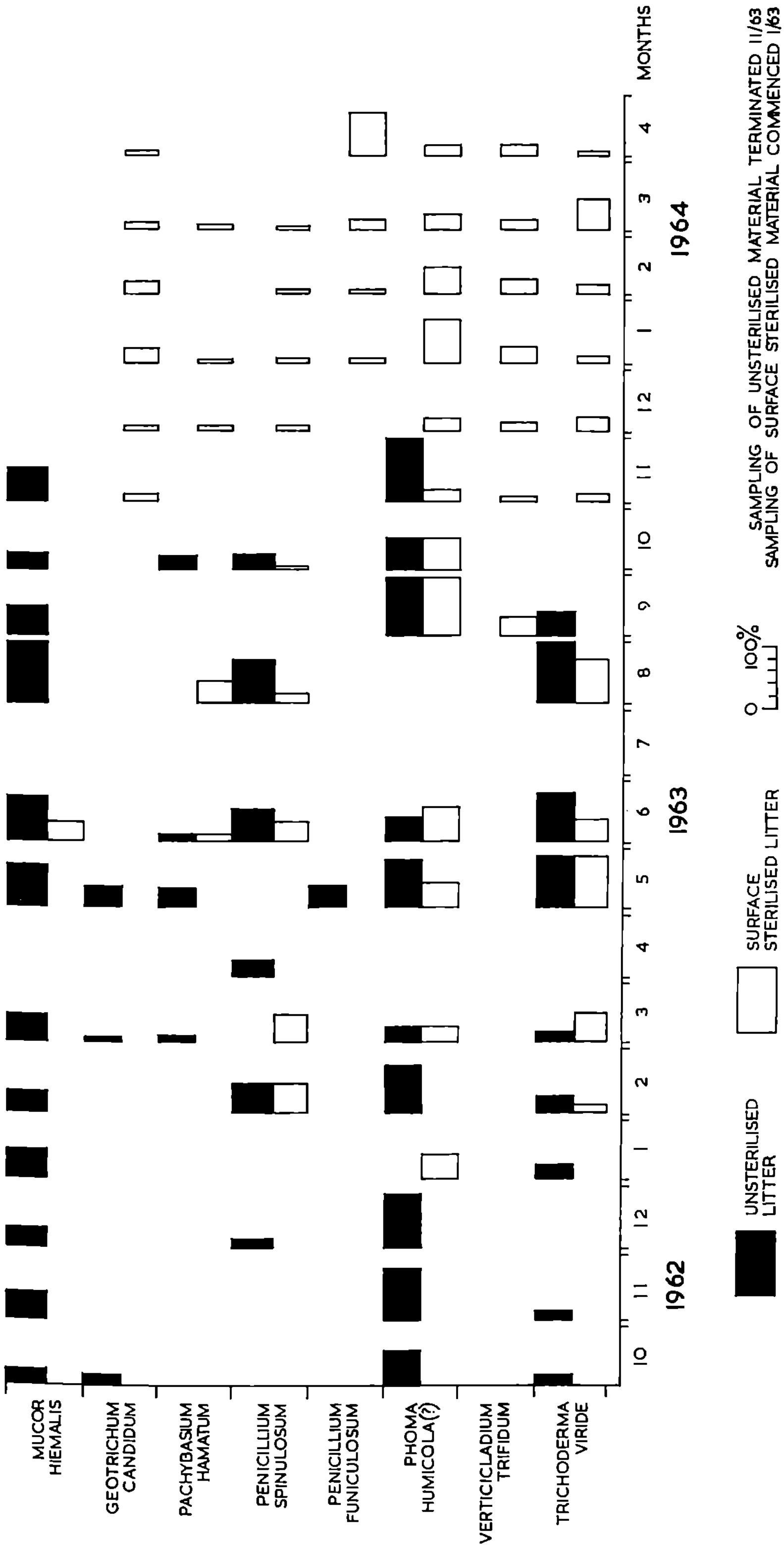

FIGURE 8. Frequency of occurrence of seven common litter microfungi on sterilised and unsterilised litter: Layer L needles.

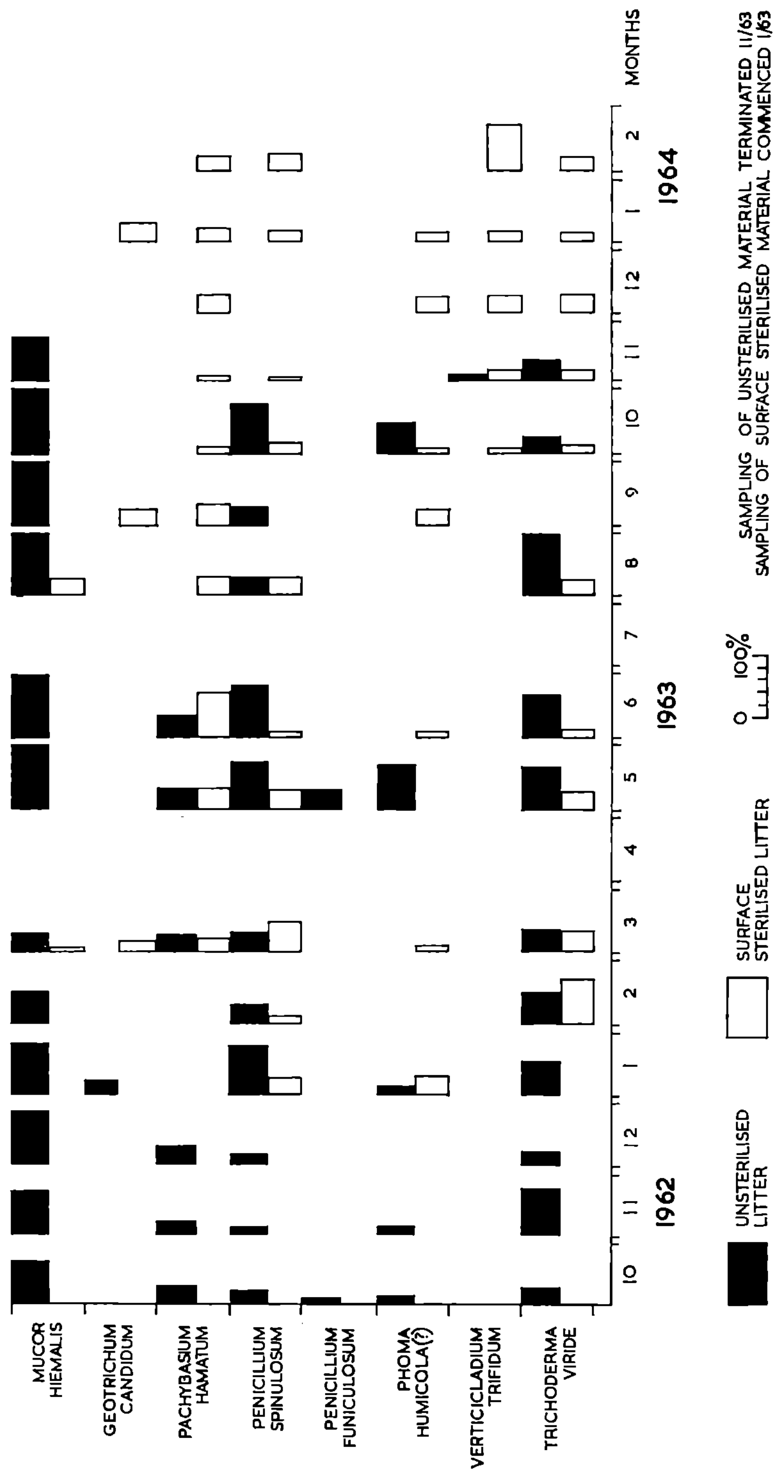

FIGURE 9. Frequency of occurrence of seven common litter microfungi on sterilised and unsterilised litter: Layer F needles.

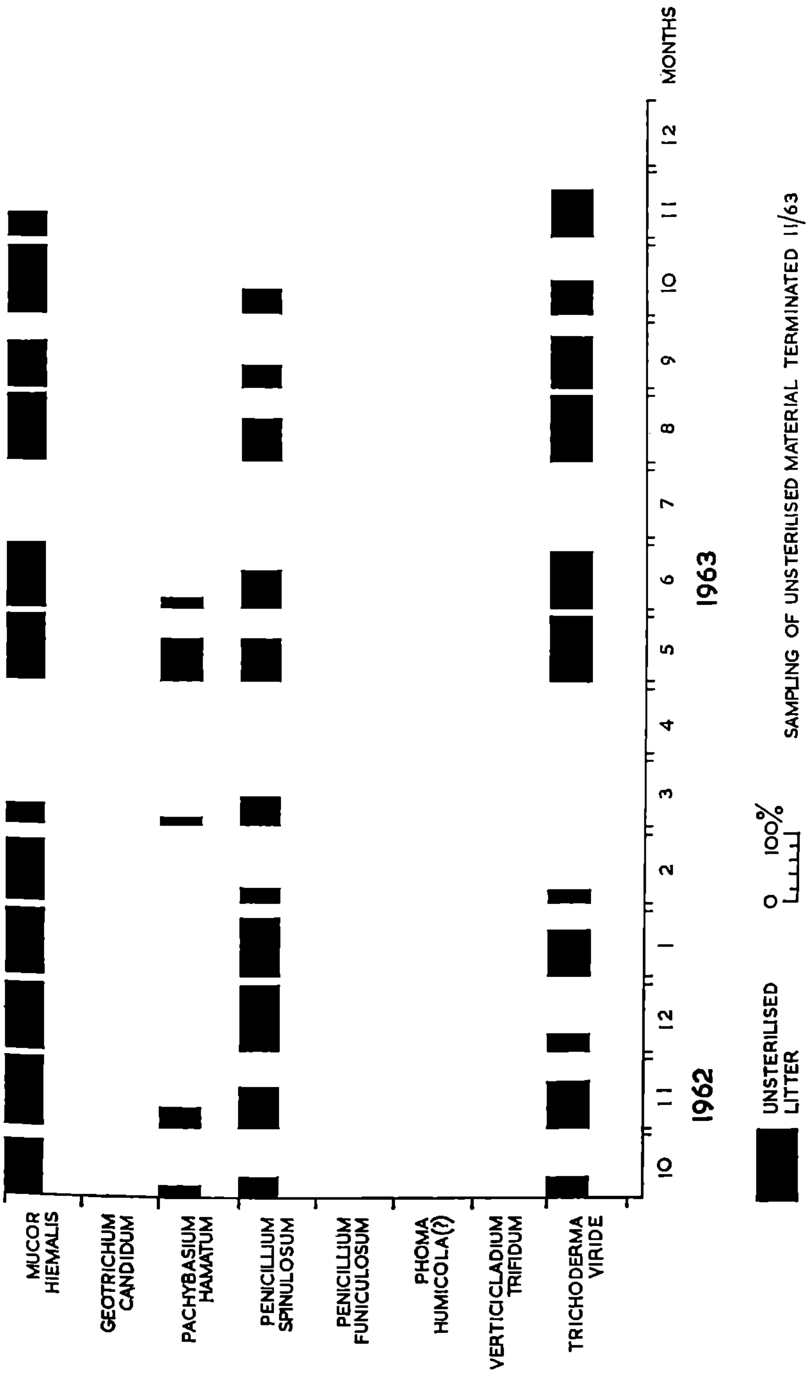

FIGURE 10. Frequency of occurrence of seven common litter microfungi on sterilised and unsterilised litter: Layer H needles.

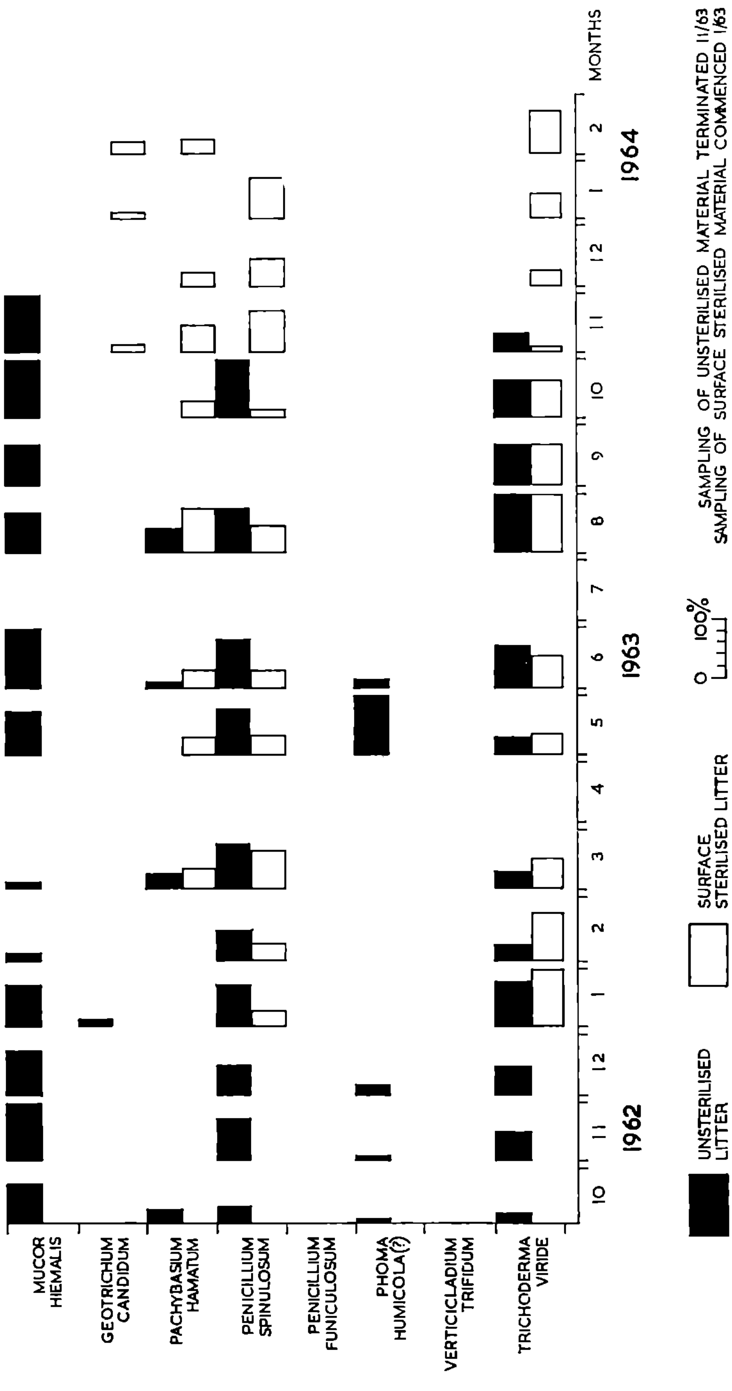

FIGURE 11. Frequency of occurrence of seven common litter microfungi on sterilised and unsterilised litter: Twig layer.

minor importance. In the later stages of decay, however, in common with the present investigation, he found that *Trichoderma viride* and *Verticicladium trifidum* were important species. Gremmen (1957) has also carried out investigations into the fungi decomposing pine litter, and has suggested that there are two stages in the process. The first, or *Sclerophoma*, stage was dominated by *Cenangium acicolum* and *Sclerophoma pityophila*, while the second, or *Desmazieriella*, stage was dominated by *Dasyschyphus pulverulentus*, *Desmazieriella acicola* and *Phialea acuum*. Of these five species, only *Desmazieriella acicola* (as its imperfect stage, *Verticicladium trifidum*) was found on the Rannoch site. In the present investigation, *Phoma humicola*(?) is the single important initial coloniser, *Penicillium spinulosum* and *Trichoderma viride* appear soon after leaf-fall, and as the litter ages, *Geotrichum candidum*, *Pachybasium hamantum*, *Penicillium funiculosum* and *Verticicladium trifidum* also appear.

Kendrick has suggested that the chemical properties of the needles exert a vigorous selection on the fungi attempting colonisation of the litter, and that thereafter it is possible that the successful early colonisers may produce fungistatic substances in turn selecting the secondary organisms. It seems likely, therefore, in view of the different fungi found to be important in the decomposition of pine litter by Gremmen, Kendrick and the writer, that differences in the site and in the microclimate influence the fungus microflora very considerably. Nevertheless, the role of *Verticicladium trifidum* as an important secondary coloniser seems to have been established.

Microdistribution of Fungi on Pine Litter

Although cultural studies on needle samples taken at random from the forest floor serve to determine the importance of the various fungal species, they provide no information on the pattern of distribution of the microfungi in small areas of the experimental site. An examination of the micro-distribution of the fungi is important since it would enable observations to be made on the successions of fungi occurring in small selected areas.

Initially, one-foot squares were chosen at random on the experimental area, and twenty evenly spaced samples were taken from them. These were surface-sterilised in the usual way before plating out, and the fungi developing on the plates recorded. These preliminary experiments showed squares dominated either by *Phoma humicola*(?), *Penicillium spinulosum*, or by *Trichoderma viride* and enclosing 'islands' of *Geotrichum candidum* or *Verticicladium trifidum*. In order to sample a single defined area on successive occasions, a block four feet by two feet was laid out within the experimental plot; two square feet being sampled each week so that the whole block of eight square feet was sampled once every month. The results of this investigation are not complete at present, but two samplings made on one of the squares indicate the rapid replacement of *Trichoderma viride* by *Penicillium funiculosum*.

Physiological Studies

Preliminary studies on the carbon nutrition of some of these fungi have been initiated prior to carrying out detailed respirometric studies on the forms considered to be important in the decay succession.

Tracer Studies Using Carbon^{14}

It may be possible to obtain evidence on the course of decomposition of Scots pine litter and on the organisms important in the process by labelling some part or parts of the Scots pine plant and then determining the fate of that labelled material as the litter decays. Dr. D. R. Gifford has initiated this study by growing seedlings of Scots pine in a closed atmosphere containing labelled carbon dioxide as sole carbon source.

Krotkov (1963) has suggested that if labelled carbon dioxide is supplied to pines immediately prior to leaf extension, the bulk of the activity becomes concentrated in the new leaves. The writer assisted in a pilot fractionation of the labelled pine material, and the results, although incomplete, indicate that the majority of the activity is concentrated in the cellulose fraction of the current season's needles.

The assistance of the Commonwealth Mycological Institute in the identification of some of the fungi is gratefully acknowledged.

Summary

The examination of the microfungi occurring on Scots pine (*Pinus sylvestris* L.) litter as it decays was continued. It is hoped ultimately to be able to determine the precise pathways of decomposition and hence determine the fate of each substance present in the litter. Approximately 120 species of microfungi have been isolated; 16 (12%) were Phycomycetes, 5 (4%) were Ascomycetes, and the remainder were Fungi Imperfecti and Sterile Mycelia. On unsterilised litter four species made up a total of 70% of the isolations, whereas on surface-sterilised litter 11 fungi made up 70% of the isolations. *Phoma humicola*(?) is the only important initial coloniser of senescent pine needles; *Penicillium spinulosum* and *Trichoderma viride* appear soon after leaf-fall, and as the litter ages *Phoma humicola*(?) gradually disappears and is replaced by such species as *Geotrichum candidum*, *Pachybasium hamatum*, *Penicillium funiculosum* and *Verticicladium trifidum* as secondary colonisers. Investigations on the microdistribution of these fungi has suggested that there is rapid replacement of *Trichoderma viride* by *Penicillium funiculosum* at certain times. Preliminary studies on the carbon nutrition of some of these fungi have been initiated prior to detailed respirometric studies, and a preliminary investigation into the distribution of radioactive carbon in Scots pine seedlings, after allowing them to photosynthesise in an atmosphere containing labelled carbon dioxide—has also been carried out.

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CHEMICAL CHANGES IN FOREST LITTER: THIRD REPORT, MAY 1964

By J. TINSLEY
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The aims of this study were set out in the first report by Tinsley and Hance (1962), while further results of the analysis of samples from experimental plots and of drainage waters from microlysimeters located at an experimental site under Scots pine at Bramshill Forest, Hampshire, were presented in the second report by Tinsley and Lennox (1963). Since the resignation of Miss Lennox at the end of 1963 the work has been kept going with part-time assistance from Mrs. E. Buchan.

Analysis of Samples from Experimental Plots

In all, each of the plots has now been sampled four times at intervals of about six months, and the results of determinations of moisture content, organic material passing the 2 mm. sieve, organic matter and nitrogen contents and pH of the sieved materials are presented for the first three sets of samples in Table 17.

A full statistical analysis of the data will be carried out at the end of the experiment but the results to date indicate slight trends. The moisture contents of the surface organic matter naturally vary with the time of sampling, but they do not show marked differences due to treatment. The limed plots give the appearance of being slightly more humified and the moisture contents are always slightly lower than the unlimed plots at sampling.

Table 17

COMPOSITION OF SAMPLES FROM BLOCKS I & II

(a) **Moisture content of samples**
Mean Percentages, each from 2 unlimed plus 2 limed plots

Fertilizer:	Urea			Ammonium Sulphate			Ammonium Phosphate		
Sample Series	I	II	III	I	II	III	I	II	III
N Level									
50 lbs/acre	50·3	63·5	61·3	51·0	60·9	61·1	47·5	64·7	63·7
100 lbs/acre	45·6	65·5	62·1	47·2	62·6	58·6	43·3	63·3	59·0
200 lbs/acre	52·3	65·5	63·0	48·8	62·4	61·8	50·4	64·1	61·7
Treatment Mean	49·4	64·8	62·1	49·0	62·0	60·5	47·1	64·0	61·5
Series	I. 22/10/62			II. 26/4/63			III. 12/11/63		
Overall Mean	48·5			63·6			61·4		
Unlimed Mean	50·3			64·3			62·1		
Limed Mean	46·7			62·9			60·6		

(b) Proportion of dry sample passing 2 mm. sieve

Mean Percentages

Fertilizer:	Urea			Ammonium Sulphate			Ammonium Phosphate		
Sample Series	I	II	III	I	II	III	I	II	III
N Level									
50 lbs/acre	69·6	80·1	81·0	71·2	81·5	78·1	67·5	82·3	76·2
100 lbs/acre	65·8	79·2	74·5	72·2	79·7	77·0	59·3	82·5	78·7
200 lbs/acre	74·9	74·6	78·0	67·5	76·4	80·7	72·3	76·8	79·3
Treatment Mean	70·1	78·0	77·8	70·3	79·2	78·6	66·3	80·5	78·1
Series	I. 22/10/62			II. 26/4/63			III. 12/11/63		
Overall Mean	68·9			79·2			78·1		
Unlimed Mean	68·6			78·0			77·6		
Limed Mean	69·1			80·4			78·6		

(c) Organic Matter content of material passing 2 mm. sieve

Mean Percentages

Fertilizer:	Urea			Ammonium Sulphate			Ammonium Phosphate		
Sample Series	I	II	III	I	II	III	I	II	III
N Level									
50 lbs/acre	68·6	76·7	67·4	70·4	81·3	68·5	65·6	81·0	74·9
100 lbs/acre	62·3	85·7	80·3	66·6	79·0	64·8	68·6	74·6	65·8
200 lbs/acre	66·9	80·8	73·7	65·9	76·5	69·7	65·1	79·7	70·0
Treatment Mean	65·9	80·8	73·8	67·6	78·9	67·3	66·4	78·4	70·2
Series	I. 22/10/62			II. 26/4/63			III. 12/11/63		
Overall Mean	66·6			79·5			70·2		
Unlimed Mean	70·1			83·2			72·0		
Limed Mean	63·2			75·8			68·0		

(d) Nitrogen content of organic matter passing 2 mm. sieve

Mean Percentages

Fertilizer:	Urea			Ammonium Sulphate			Ammonium Phosphate		
Sample Series	I	II	III	I	II	III	I	II	III
N Level									
50 lbs/acre	1·49	1·49	1·55	1·40	1·44	1·50	1·53	1·51	1·42
100 lbs/acre	1·38	1·54	1·41	1·41	1·61	1·56	1·34	1·59	1·60
200 lbs/acre	1·56	1·50	1·55	1·60	1·51	1·69	1·55	1·48	1·54
Treatment Mean	1·48	1·51	1·50	1·47	1·52	1·58	1·47	1·53	1·52
Series	I. 22/10/62			II. 26/4/63			III. 12/11/63		
Overall Mean	1·47			1·52			1·53		
Unlimed Mean	1·45			1·49			1·53		
Limed Mean	1·50			1·55			1·53		

e) pH values of material passing 2 mm. sieve

Fertilizer:	Urea			Ammonium Sulphate			Ammonium Phosphate		
Sample Series	I	II	III	I	II	III	I	II	III
N Level					Unlimed				
50 lbs/acre	3·59	3·64	3·40	3·35	3·40	3·38	3·30	3·48	3·20
100 lbs/acre	3·65	3·56	3·60	3·20	3·50	3·02	3·34	3·54	3·30
200 lbs/acre	4·06	3·94	3·55	3·52	3·57	3·30	3·78	3·89	3·50
Mean	3·77	3·71	3·51	3·37	3·51	3·23	3·47	3·64	3·33
N Level					Limed				
50 lbs/acre	5·89	6·05	6·10	5·98	6·05	6·05	6·00	5·90	6·05
100 lbs/acre	5·81	5·78	5·78	6·01	5·95	5·40	5·89	5·98	5·52
200 lbs/acre	6·12	6·09	5·80	6·15	6·02	6·10	5·66	5·72	5·43
Mean	5·94	5·98	5·56	6·05	6·01	5·83	5·85	5·87	5·67

Table 18

NITROGEN CONTENTS OF FOLIAGE SAMPLES (1962)

Mean Percentage of dry matter

Fertilizer:	Urea		Ammonium Sulphate		Ammonium Phosphate	
N Level	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed
50 lbs/acre	1·52	1·73	1·43	1·63	1·75	1·15
100 lbs/acre	2·01	2·37	1·61	1·85	1·74	1·46
200 lbs/acre	1·87	2·02	1·68	1·84	2·18	2·01
Mean	1·80	2·04	1·57	1·77	1·89	1·54

The amount of material not passing the 2 mm. sieve after drying is an arbitrary measure of undecomposed needles, twigs, and cones, and it is seen from Table 17, section b, that at the second sampling in the spring of 1963 the proportion had decreased from about 31 per cent to 21 per cent, and by the third sampling was about 22 per cent.

The mean organic matter content of the oven-dry sieved material was 66·6 per cent at the first sampling, with little difference between nitrogen treatments but a distinct difference due to liming. At the second sampling the organic matter content had risen to a mean of 79·5, presumably due to the fall of fresh litter during the intervening winter months, and at the third sampling it had fallen to 70·2 per cent with a smaller difference between limed and unlimed plots than at the beginning.

The nitrogen contents of this organic matter (ash-free) show only small differences due to level of nitrogen fertiliser, with a tendency to stabilize at about 1·53 per cent in the third sampling, by which time there was no difference between the limed and unlimed plots. Similarly the pH values showed little difference between nitrogen treatments by the third sampling.

Analysis of Drainage Samples from Microlysimeters

The analyses have been continued and the overall trends shown in graphical form in the second report have continued, so no results are presented now, but will be given in full at the end of the experiment.

Analysis of Leachates from Laboratory Columns

As intimated in the previous report, a fresh set of columns were established in July 1963 to test the effect of nitrogen fertiliser treatments on the rate of leaching of base cations from the surface organic horizon of the soil, and the results of these analyses will be reported after they are completed later this year.

Analysis of Components Soluble in Formic Acid

This work was briefly reported last year, but further progress was interrupted by the resignation of Miss Lennox. However, her successor, who will commence work on October 1st, 1964, will concentrate activities on this section of the work now that the main samples have been collected from the field plots.

Foliar Analysis

Samples of foliage collected and analysed by the Forestry Commission staff, and the results of the first samples, provided by Dr. Binns, are given briefly in Table 18 without any statistical analysis at this stage.

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HYDROLOGICAL RELATIONS OF FOREST STANDS

By L. LEYTON and E. R. C. REYNOLDS
Department of Forestry, Oxford University

The Water Balance

The ultimate aim of this research programme is to make a quantitative study of the factors operating in the hydrological balance of forests in relation to different systems of management. The field work has been largely carried out in a c. 20-year-old plantation of Norway spruce in Bagley Wood, near Oxford, and much time has been spent in devising and testing techniques suited to routine measurements of the various phases of the hydrological cycle. This development work has now been virtually concluded, and plans are now going ahead to investigate the effect of various silvicultural treatments on the hydrological balance. In the winter of 1963, the plantation was thinned to about 80% of its previous basal area, and it is planned to impose later a further thinning in two sub-plots to allow for the comparison of differential thinning effects.

The problems involved in the measurement of rainfall above the canopy and the results obtained using various types of gauge and shield have been discussed in the *Meteorological Magazine* (Vol. 92, 210–213, 1963: Vol. 93, 65–70, 1964). Little more can be done without more comprehensive tests on the aerodynamics of rain gauge shields, e.g. in wind tunnels: in the meantime measurements are being continued using two 60° Nipher shields with standard 5 in. gauges, these having appeared to be the most reliable in previous tests.

The results of a number of years' measurements on interception, throughfall and stem flow and the significance of these phases have been discussed in the *Water Relations of Plants*, published in 1963 by Blackwell Scientific Publications (p. 127–141). Recent modifications in the techniques used include:

(1) The installation of annular gauges to improve measurements of throughfall in the vicinity of the tree stems.

(2) Replacement of copper tipping buckets by ones made of fibre glass, and of microswitches by tipping mercury switches for the automatic measurement of trough throughfall catches.

The thermal flow technique for the determination of sap flux in tree stems has now been developed to a stage where it can be applied to automatic measurements in the field. Local heating of the stem has been simplified by passing alternating current through a resistance wire wound round the stem, usually for about 15 seconds; the resulting heat flux (which is determined among other things by the sap flux) is recorded as the difference in temperature between a large number of thermo-junctions inserted around the stem, about 2 cm. on either side of the heater. An apparatus has been constructed which, working from a master time clock, automatically applies heat pulses at given time intervals to a number of trees in succession and continuously records the temperature response curves on a multipoint millivoltmeter. A number of successful runs have been made on Norway spruce trees over 24–hour periods. In order to calibrate the temperature response curves in terms of absolute loss of water by transpiration from the crown, the latter is completely enclosed in a plastic bag through which air is blown and transpiration determined from the measurement of air-flow rates (using an array of Pitot tubes) and of changes in moisture content (using wet and dry thermocouples). The original polythene bag has been replaced by one of Melinex (ICI) which is much stronger and more transparent. Using the time interval to the peak as the most convenient parameter of the heat flux response, simultaneously with transpiration measurements, calibration curves have been obtained which can be applied to routine measurements. These investigations are now being written up for publication.

Although the above technique has proved successful enough, it is limited to measurements of transpiration at particular intervals, and a method is now being investigated which it is hoped will allow for the continuous recording of sap flux. Consideration is also being given to a modification of the method for measuring absolute water loss from the crowns, which involves a closed circulatory system in which water lost is condensed and measured directly. This would considerably simplify the calibration procedure.

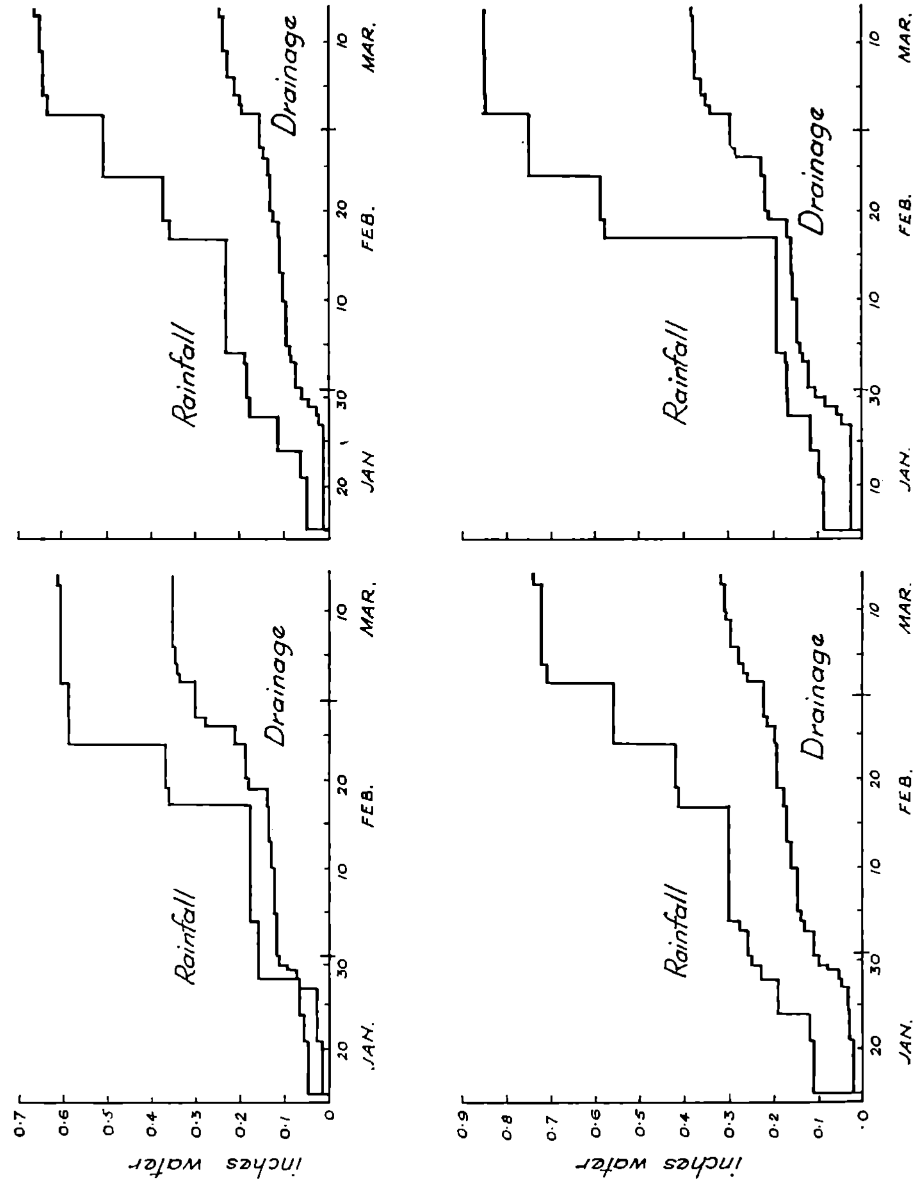
For the measurement of evaporation from the forest floor, 6 miniature lysimeters have been constructed, each 2 ft. square and 3 in. deep: these are filled with undisturbed humus, installed flush with the forest floor, and subjected to a continuous tension of 100 cm. water to simulate natural drainage conditions. Rainfall (throughfall) on each lysimeter is determined by a rain gauge moved to a new position after each rainy day. Figure 12 illustrates the cumulative rainfall and drainage values for each lysimeter for the period mid-January to mid-March. It will be noted that drainage can extend for more than one week after a storm. For the two months in question, throughfall in the different lysimeters ranged from 0·6 to 1·1 in. and evaporation (calculated as the difference between throughfall and drainage) from 0·25 to 0·6 in. In terms of water accession to the soil, therefore, such losses by evaporation are by no means insignificant, though it must be remembered that this period was unusually dry; it will be interesting to see how much water is lost in this way during the summer months. It is also of interest that the wetter lysimeters lost more water by evaporation, so that as far as soil moisture replenishment is concerned, differences in throughfall which are very characteristic of forest stands were to a large extent compensated by differences in evaporative losses.

Measurements of soil moisture distribution patterns have been made, using arrays of tensiometers and nylon resistance units installed at different depths and at varying distances from tree stems. Because of stem-flow the accession of water to the soil is very much greater around the base of the stems, and a technique is being developed, using fluorescent dyes, to follow in more detail the movement of water in the soil in this region.

Evidence has been obtained from laboratory investigations that although wetting of the foliage reduced transpiration, intercepted water may evaporate off at such a rate that the compensation is only partial. This would suggest that interception losses may play an important role in determining the net yield of water from catchments under forest. Preparations are being made to investigate this phenomenon in the field in terms of changes in the heat energy budgets when tree canopies are wetted by rain.

Soil Moisture Depletion by Roots

It has been recognized that for a fuller understanding of the influence of vegetation on water yields from catchments, more knowledge is required about


Rainfall
Drainage
inches water
JAN.
FEB.
MAR.

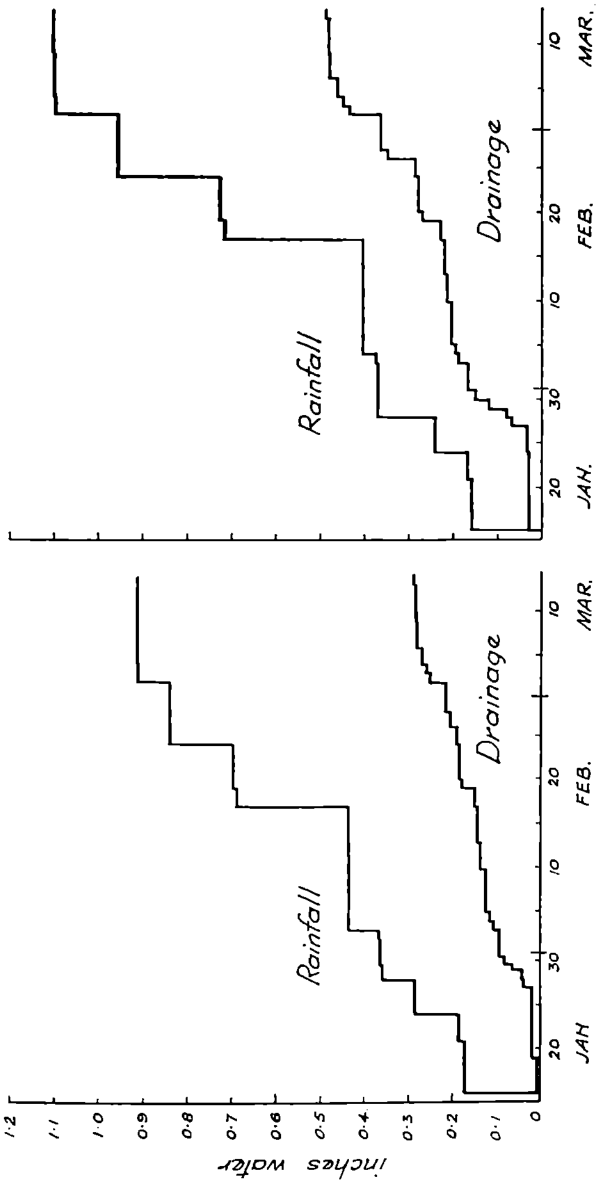


FIGURE 12. Cumulative rainfall and drainage from six lysimeters filled with raw humus and randomly distributed under a Norway spruce plantation; Bagley Wood 1964.

the distribution and activity of roots in water uptake from the soil profile. To facilitate the determination of root distribution patterns, apparatus has been constructed for the routine separation of roots from samples of soil obtained by a specially constructed auger (designed by W. H. Hinson). At the same time methods are being investigated whereby soil moisture depletion patterns around root systems can be identified: attention so far has been directed to producing visible soil moisture distribution patterns on freshly exposed soil profiles, using powders incorporating moisture-sensitive dyes. The relation between rooting depth and direct abstraction of water from the soil is being studied under a plantation of hornbeam in Bagley Wood, using water level recorders in wells.

Interception and Infiltration of Water under Different Moorland Vegetative Covers

The aim of these investigations is to complement the work done on tree covers with relevant hydrological information on alternative vegetative covers of importance in moorland catchments, namely heather, grasses (*Molinia*) and bracken. Mr. F. B. Thompson, who recently joined the section, has made a survey of possible sites, and it is intended at the beginning to work on the moors in the vicinity of Halifax, Yorkshire, where local co-operation has been promised and is gratefully acknowledged. It is proposed to lay out a number of 1-metre-square sample plots, and to seal the soil surface below the vegetation so as to allow for the determination of total interception under different rainfall conditions. Tests have been made on various surface-sealing compounds including waxes, silicone rubbers and neoprene latex, and techniques of application have been investigated.

Recognizing the advantages of automatic measurements in isolated areas, much attention has been paid to the design of an instrument for the simultaneous recording of rainfall and surface run-off. An experimental model has been constructed incorporating a double tipping bucket system to deal with high and low flows and a clockwork strip chart mechanism.

The support of the Forestry Commission in providing for technical assistance (Mr. E. A. S. Ogden) is again gratefully acknowledged.

FIRES IN FOREST AND HEATHLAND FUELS

by P. H. THOMAS and D. L. SIMMS
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The main emphasis has been on the spread of fires in still air, and the work has now reached a stage at which satisfactory predictions of such fire-spread in uniform beds of fuel are now possible. Some progress has been made in the study of the effect of wind. To relate experimental and theoretical work to practical conditions it is now necessary to make a systematic collection of data on wild-fires and experimental fires in forests.

The work of the year is described in more detail.

Fires in Cribs

It has been shown (Thomas and Simms 1964) that the spread of fire in cribs in still air can largely be attributed to the radiation from the main body of the burning fuel transmitted through the unburnt fuel, the flames above the fuel contributing little to the spread. This means that over a certain range of conditions the product of R, the rate of spread, and the bulk density ρ_b of the fuel bed is approximately constant. This view has been supported by the recent work of McCarter and Broido (1964). The theoretical model of this form of fire-spread has been extended to allow for the effect of moisture on the thermal properties of the fuel bed.

Fine Fuels

The above interpretation of crib results has been applied to the results of experiments on beds of fine fuels reported by Curry and Fons (1940) and Anderson (1964). Heat transfer conditions in such beds depend on λ, the ratio of the volume of voids to surface, but the effect is small for $\lambda > 0{\cdot}3$ cm which covers most practical conditions. Very tightly packed fuels having low λ burn more slowly, and for very low λ they smoulder.

Flame Heights

The length of flame L of an advancing fire front of thickness D has been determined (Thomas 1963) and, provided $L/D > 2$, is given by:

$$L \doteqdot 400\, m^{\frac{2}{3}} \qquad \ldots\ldots\ldots\ldots(1)$$

where L is in centimetres and m is the mass of fuel consumed per unit length of fire front per second in g $cm^{-1}s^{-1}$.

Since for a given bulk density of fuel, m is directly proportional to the depth h of fuel burnt, it follows, because of the two-third power law, that L is less than proportional to h. Therefore the contribution of the flame radiation in still air, relative to that through the fuel bed, decreases for deep beds.

It can be shown that equation (1), which is based on dimensional analysis, is in good agreement for low rates of burning with an empirical formula given by Byram (1959) based on his own field data, and also with the data of Van

Wagner (1963) obtained from experiments in quarter-acre stands of red pine and white pine in Canada.

A wind has little effect on the flame length, but the height H of the deflected flame is reduced. A comparison has been made between a field experiment in France and the equation for flame height in dimensionless form based on laboratory experiments (Thomas and Scott 1963):

$$H\left(\frac{g\rho_o}{m^2}\right)^{\frac{1}{3}} = 38\left(\frac{U\rho_o^{\frac{1}{3}}}{(mg)^{\frac{1}{3}}}\right)^{-0{\cdot}69} \quad \ldots\ldots\ldots\ldots(2)$$

where g is the acceleration due to gravity

ρ_o is taken as $1{\cdot}3\times10^{-3}$ g/cm^3

m is the mass of fuel consumed per unit length of fire front

and U is the wind speed.

The data from the large-scale experiment at Trensacq, France, in 1955 (Faure 1961), where 803 acres of waste heathland were burnt, agree well with this expression. The fuel was about 1 metre high and the fuel load about 1·7 kg/m^2. The observed flame height H was approximately 11–12 metres, and compares well with the calculated value of 11·5 metres obtained from equation (2). The rate of spread in a wind of 5–8 metres per second was estimated at about 1·1 metres per second. The rate of burning against the wind was about 3 mg cm^{-2}s^{-1}, somewhat less than the values estimated for still air (5—8 mg cm^{-2}s^{-1}) but of the same order of magnitude, whereas the rate of burning in the direction of the wind was over fifty times faster.

The Effect of Wind on Spread

The spread of fire in a wind is less well understood than spread in still air. For example, experimental work has shown that the effect of increasing the wind speed on a fire in cribs is much more pronounced when the crib sides are not enclosed. Amongst the main mechanisms of fire-spread are:

(a) Radiation transfer through the fuel bed (important in still air, low wind speeds and deep fuel beds).

(b) Convective transfer (including transport of brands) through and above the fuel bed (important with shallow beds and high wind speeds).

(c) Radiation from the flames (possibly dominant with thick flames produced by large fires which involve fuel of large cross-section, thus having a long burning time).

Past experimental work is being analysed and future work will be directed towards establishing the role of these various regimes in fire situations.

Work in the laboratory has now reached the stage where the behaviour of actual fires, controlled burns, and the predictions from laboratory and experimental fires, can profitably be compared. Arrangements are now being made with the Forestry Commission for the relevant data to be collected.

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OAK POPULATION STUDIES: V. QUERCUS ROBUR L. POPULATIONS ON FLOOD-PLAIN SITES IN YUGOSLAVIA

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The status of Pedunculate oak, *Q. robur* L., in Britain could not be diagnosed with any confidence from populations sampled up to 1962 (See *Rep. For. Res.* 1963). The problem would be resolved if 'good' *robur* populations could be found on the continent. The most promising localities appear to be (a) the western slopes of the Urals, because the Sessile oak, *Q. petraea* (Matt.) Liebl. does not extend that far east and (b) the flood-plain oakwoods of the Danube and its tributaries, where the soil-water regime should completely exclude the oxyphilic *petraea*. In July 1963 a nine-day visit to Yugoslavia was arranged. The Notes on page 125 give some details of the collections made there.

Robur specimens collected proved, once again, to be very variable; 36% of them could be allocated to the Theoretical Species Type (*Watsonia* 5 (5), 1963) as compared with 17% in the English collections and 10% in the Scottish collections. The data do not provide any real evidence of introgression by *petraea*, although characters which could be attributed to *petraea* appear frequently. For example, adaxial stellate pubescence on the leaves occurs on 14 out of the 206 *robur* specimens collected; but it is associated with longer-than-average peduncles and shorter than average petioles. If the presence of this pubescence is due to introgression it is more likely to have come from a species such as *Q. pedunculiflora* K. Koch (which occurs not far away to the east) than from *petraea*. Peduncle pubescence occurs on 40% of the specimens; but there is no predominance of such forms among those specimens with the combination short-peduncles-long-petioles (i.e., on the introgression path from *petraea*). Only one character, the medium auricle, occuring on 49 (24%) of the specimens, showed a concentration (17) on the introgression path from *petraea*; but there were no weak auricles and the auricle characters should, perhaps, be re-examined. One population sample (Strupnićki Lug) had an unusually large proportion of low values for length of peduncle to first bract; it was also a lightly flooded area with *petraea* only about half a mile away on a low ridge; but the petiole % values were normal for *robur*.

It seems that *Q. robur* L. must be accepted as a poorly defined species. This could be due to introgression from related species or to incomplete divergence during its evolution. Certainly the position in Scotland can be attributed to introgression following Man's planting activities, but the extent of prior introgression unaided by Man must remain a matter for conjecture. The enforced migrations during the Ice Ages seem likely to have created conditions favourable for introgressive hybridization. By the time *robur* appeared again in Britain after the last glaciation it may well have become almost as introgressed as it appears to be in England now. The possibility of introgression by several related species must be borne in mind, and it would not be surprising to find that *robur* in the Urals was also very variable, even though out of the range of *petraea*.

The Forestry Faculties of the Universities of Belgrade and Zagreb very kindly assisted with arrangements for the tour. Particular thanks go to Professor Androić, Professor Anić and their colleagues in Zagreb and to the staff of the British Council in Belgrade.

Notes on Localities in which Collections were made in Yugoslavia

1. **Strupnićki Lug** (20 specimens). 120-year-old oak with hornbeam and some beech; rather open in places.
   Very edge of flood-plain south-west of Zagreb—low hills with *petraea* about half a mile away. Collections in Cpt. 12 from trees round gaps (on the north-west side).
2. **Turopolski Lug** (34). 94-year-old oak, pure, closed canopy. Isolated 4,200 ha. forest south of Zagreb.
   Collections in Cpt. 9B in which observations were being made on the consistently late-flowering forms (var. *tardissima*).
3. **Lipovjani** (41).The Josip Kozareć Forest on the Sava, 60 miles downstream from Zagreb.
   Typical Slavonian Oak Forest—Quercetum roboris-genistetum. *Q. robur* with *Fraxinus angustifolia* Vahl. dominant in the hollows where the water lies longest and some *Ulmus carpinifolia* Gled. are the main timber species. Flooding lasts one to two weeks each spring. With shorter and less regular flooding there is a gradation to *Quercetum-carpinetum*. Small unflooded islands carry *Q. robur—Q. cerris* forest with *Tilia argentea* DC. and *T. cordata* Mill.—presumably much of the surrounding agricultural land carried such forest at one time. Collections were made along the light railway tracks (in Cpts. 101, 102, 106 and 107 mainly) but even so very few were fertile (18).
4. **Sremska Mitrović** (85). The Sumsko Gazdinstvo, a combined Forestry-Agriculture organisation, manage 21,000 hectares of the old Slavonian Oak Forest west of Sremska Mitrovic. All these forests have a long history of uncontrolled exploitation, and even now, 80 years after the introduction of planned management, stocking is often rather low. No areas have been clear-felled more than once, and natural regeneration has been adequate. The Working Plan stipulates a 160-year rotation for the oak, with the ash being removed at 90 years.
   There are huge areas planted with poplars on the deeper flooded ground near the Sava and the Bosut.
   Four separate collections were made in this area:
   (a) **Vratićna Stara.** Reserve of trees over 300 years old, very open now. Of 34 specimens taken on a traverse, only 22 were fertile. Soil said to be the typical 'para-podzol' (pH 5–6) of the *Quercetum roboris—genistetum*.
   (b) **Domoskela**—a small rather open patch near the homestead of this name.
   (c) **Ćret**—a dense stand on river alluvium which had to be sampled along its southern margin.

(d) **Klještavića** The smallest mature trees seen—canopy height about 60 feet—north-eastern edge of flood-plain on calcareous soil (pH 7·5-8·5)—sampled along the south-eastern margin.

5. **Požerevać** (55). The remains of marginal flood-plain forest about two miles from the river Morava and south-east of Belgrade near Ljubičevo. The oaks, said to be over 250 years old, are now scattered through pasture; most of the trees were fruiting heavily and only one sample was infertile.
6. **Miscellaneous** (20). A number of small collections were made in the Zagreb area and on a speculative visit to the region around Smedreska Palanka, south of Belgrade.

'Hybrid Indices', calculated as in previous reports, are:

Strupnicki Lug	1·45	Domoskela	1·10
Turopolski Lug	1·32	Cret	1·14
Lipovjani	0·94	Kljestavica	0·74
Vraticna Stara	0·64	Pozerevac	1·06

Summary

From a study of *Q. robur* L. populations in the flood-plains of the rivers Sava and Morava in Yugoslavia it seemed, as expected, that these are sites in which introgression from *Q. petraea* (Matt.) Liebl. is negligible if it has occured at all. However, *robur* is still extremely variable. It may be an incompletely divergent species, but introgression by closely related species other than *petraea* (e.g., *Q. pedunculiflora* K. Koch) seems more likely.

OAK POPULATION STUDIES VI: OAK SURVEYS IN SCOTLAND

By D. C. MALCOLM

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University of Edinburgh.

During the period under report the pilot survey of oak populations in Galloway (counties of Wigtown and Kirkcudbright) was completed.

Using the same methods for selecting the oak stands to be visited as in the previous period (2), some 118 stands, extending over 2,022 acres, were examined. A preliminary systematic sample was used to reject populations with a significant proportion of individuals displaying affinity with *Q. robur*. Collections representing in total 327 individuals were made in 18 stands which, in the field, appeared to be homogeneous *Q. petraea* populations. In addition three stands in Glentrool Forest (Glenhead, Buchan, and Caldons Woods), which were sampled during the early taxonomic work by Cousens, and which formed the main basis for the description of the theoretical species type (2), were resampled by a collection of 73 individuals to confirm their homogeneity as *petraea* populations. A few other small collections amounting to 30 specimens were made from old trees in groups not large enough for sampling.

Upon carrying out the analysis of the data and the preparation of the scatter diagrams for these collections, (Cousens 1963), seven homogeneous *petraea* populations were recognised on the basis of the two main characters of petiole ratio and peduncle distance to first bract. These are shown in col. 4 of Table 19 indicating the proportion of the sample falling within the limits set for these characters. If the four subsidiary characters are taken into account it is possible to calculate a 'heterogeneity index' (H.I.) for the population as the ratio of the total number of differences a population sample shows from the theoretical species type to the number of individuals in the sample. By definition, the theoretical species type does not include the whole range of variations of the subsidiary characters. Only part of the heterogeneity demonstrated should therefore be attributed to introgression. It is likely then, that any stand defined on the basis of the main characters as homogeneous and with a H.I. value of about 1·0 or less will not be introgressed. Applying this value to the current collections reduces the satisfactory populations to six.

The result of two years' collections in the survey of all the Galloway oakwoods has been to demonstrate that only 13 stands, out of a total of 170 pre-dating 1756, can be considered as homogeneous *petraea* populations. This is despite the overwhelming abundance of individuals of *petraea* affinity over those of *robur* affinity. As there is no evidence which would lead one to doubt the definition of the theoretical species type, these results support the tentative conclusions reached after the general sampling over the rest of Scotland that the apparent massive introgression of *Q. petraea* has resulted from the introduction of hybrid and aff. *robur* forms through planting. It might be, of course, that *petraea* was already introgressed to some extent before reaching this area postglacially, but there is little evidence to uphold this view. The 'good' *petraea* populations, in general, are so situated and have associated species such as to

Table 19

Oak Survey in Galloway

O.S. Ref. (1)	Sample size (2)	Heterogeneity Index (3)	Proportion of individs. within *petraea* def. % (4)	Origin of stand (5)	Current land use (6)	Locality name (7)
6188	25	1·44	84	coppice	grazed	Blackwater
6084	13	1·0	77	coppice	grazed	Knockmalling
6772	13	1·08	92	coppice	woodland	Nether Ervie
6574	34	1·0	82	coppice	woodland	Shirmers
5980	21	0·66	90	coppice	woodland	Old Glenlee
6869	22	0·91	100	planted/natural	woodland	Hensol House
5854	17	0·43	100	copp/natural	woodland	Ardwall
5960	15	1·2	100	coppice	woodland	Castramont Wood
5654	29	0·17	100	unsingled copp.	woodland	Cardoness Wood (east)
5654	14	0·86	100	singled copp.	woodland	Cardoness Wood (west)
5553	14	0·80	100	planted/copp.	grazed	Old Land
5655	14	0·57	93	coppice	grazed	Upper Skyreburn
5655	19	0·43	95	coppice	grazed	Lower Skyreburn
6580	10	0·70	90	copp/nat.	scrub	Holy Linn
8254	12	0·16	100	coppice	grazed	Castle Hill
8855	15	0·66	93	coppice	grazed	Drumburn
8855	22	0·45	95	coppice	grazed	Laggan/Barend
9055	18	0·66	94	coppice	holiday huts	Heughwood

Note: O.S. Reference is to National Grid: Square NX. All the places named lie in Kirkcudbrightshire.

suggest that they are, by comparison with most stands, of long standing and relatively undisturbed. There is no proof that they are derived from indigenous stock but they are more likely to be than any others.

The indication from collections in other parts of Scotland is that there is less likelihood of finding reasonable numbers of satisfactory *petraea* populations, so that it is felt that the survey should not be extended to the rest of the country at present. It is considered that a satisfactory technique has been evolved with which to assess any oak population and that this assessment, together with other relevant considerations, could be used to determine the desirability of retaining a population in existence which might be of native origin.

Fortunately the best of the homogeneous populations of *Q. petraea* in Galloway are in control of the Forestry Commission, and should have an assured future, without the introduction of extraneous genotypes. The owners of the other stands might be encouraged to perpetuate them, where this is still possible.

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(2) Cousens, J. E. and Malcolm, D. C. *Rep. For. Res., For. Comm.* 1963.

PHYSIOLOGICAL STUDIES ON THE ROOTING OF CUTTINGS

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Hormone Studies

The two previous reports have dealt with the rooting responses of hardwood and leafy cuttings of poplar as related to bud dormancy and environmental factors. The present report describes studies of the endogenous hormones of poplar (*Populus* 'Robusta') and their seasonal variation, especially in relation to the rooting of cuttings.

The hormones were extracted by conventional methods and separated into "acidic" and "neutral" ether-soluble fractions, which were then partitioned by paper chromatography. Hormone activity was assayed primarily by the oat mesocotyl and coleoptile tests, but also by means of a test involving the rooting responses of hypocotyls of French bean seedlings.

It was found that poplar shoots contain both an acidic hormone which corresponds in its properties to β-indole-acetic acid (IAA), and a neutral hormone which may be indole-acetonitrile (IAN). Both the neutral poplar hormone and authentic IAN were found to stimulate the rooting of bean cuttings, but disbudded poplar did not form roots in response to exogenously applied IAN.

A study was carried out of the hormone changes occurring in leafy cuttings following their planting in a rooting medium in July. Samples were collected for extraction:

(a) Immediately on taking the cuttings, and

(b) After five days in the rooting medium.

The basal 5 cms, and the upper portions, of the cuttings were extracted and assayed separately. It was found that there was a large increase in the level of the acidic and neutral hormones in the basal region of the cuttings during the first five days in the rooting medium, but this increase did not occur in the upper portions of the cuttings. It was found that roots emerged from the base of cuttings after five to nine days.

A comparison was made of the hormone levels in:

(a) Actively growing leafy cuttings

(b) Leafy cuttings which had been rendered dormant by previous short-day treatment

(c) Defoliated dormant cuttings

It was found that dormant leafy cuttings contain significantly less neutral hormone than actively growing ones, and the hormone level is further reduced by defoliation.

The changes in the levels of acidic and neutral hormones were also studied in hardwood cuttings following planting. The cuttings were taken in February, after exposure to natural winter chilling, and planted under warm conditions. The level of the acidic hormone was found to increase markedly during the first six days after planting, when the buds were swelling, but fell to a low level after twenty-one days.

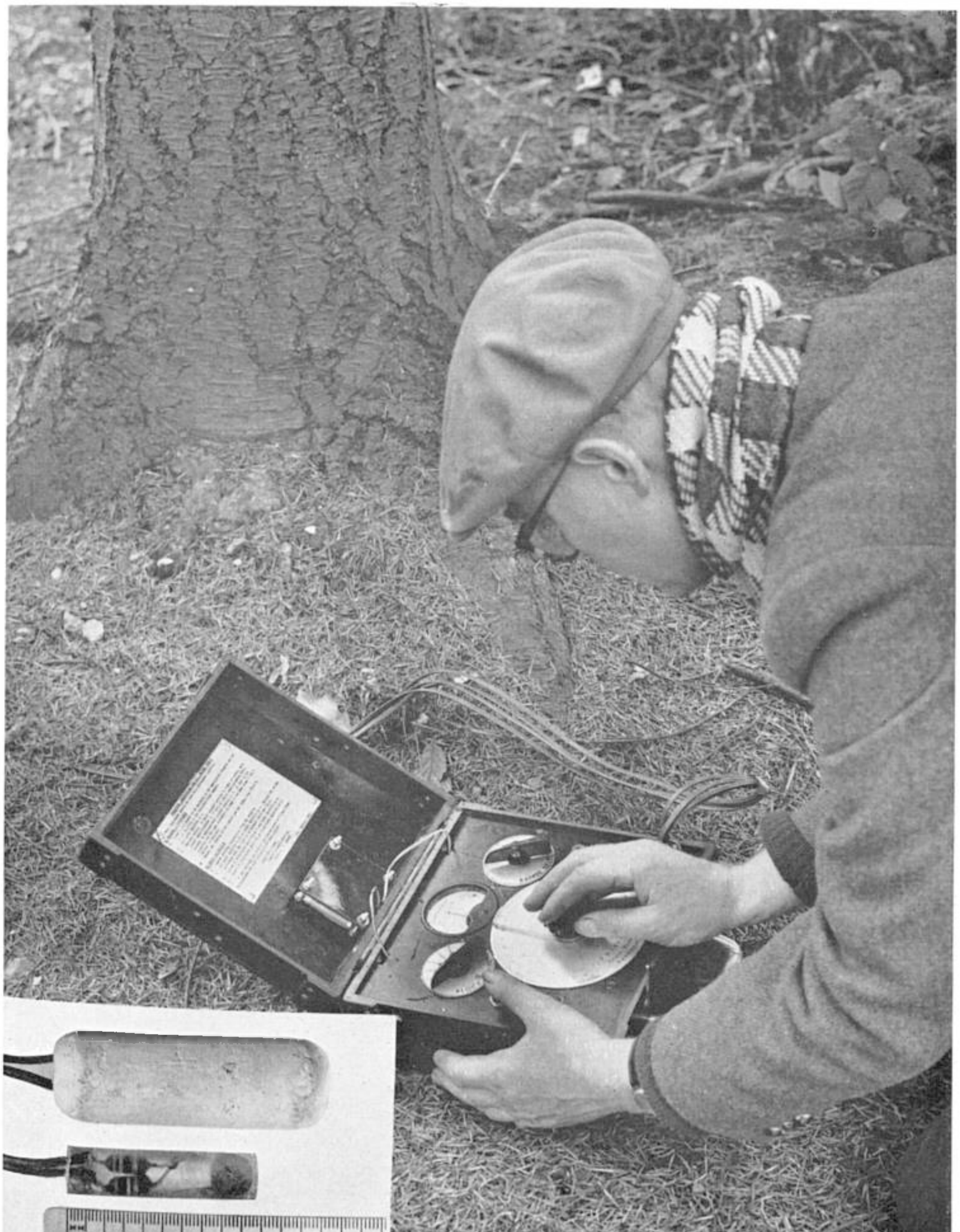

PLATE 1. Binns et al; Forest Soils.

Use of portable alternating current bridge for soil moisture and temperature measurement.
Inset: Gypsum soil moisture block and encapsulated thermistor.

PLATE 2. Faulkner et al; Genetics.

General view of the seed orchards at Clanna, Forest of Dean. Larch (tallest) at left, centre, and right background; Scots pine, foreground; Douglas fir, centre background.

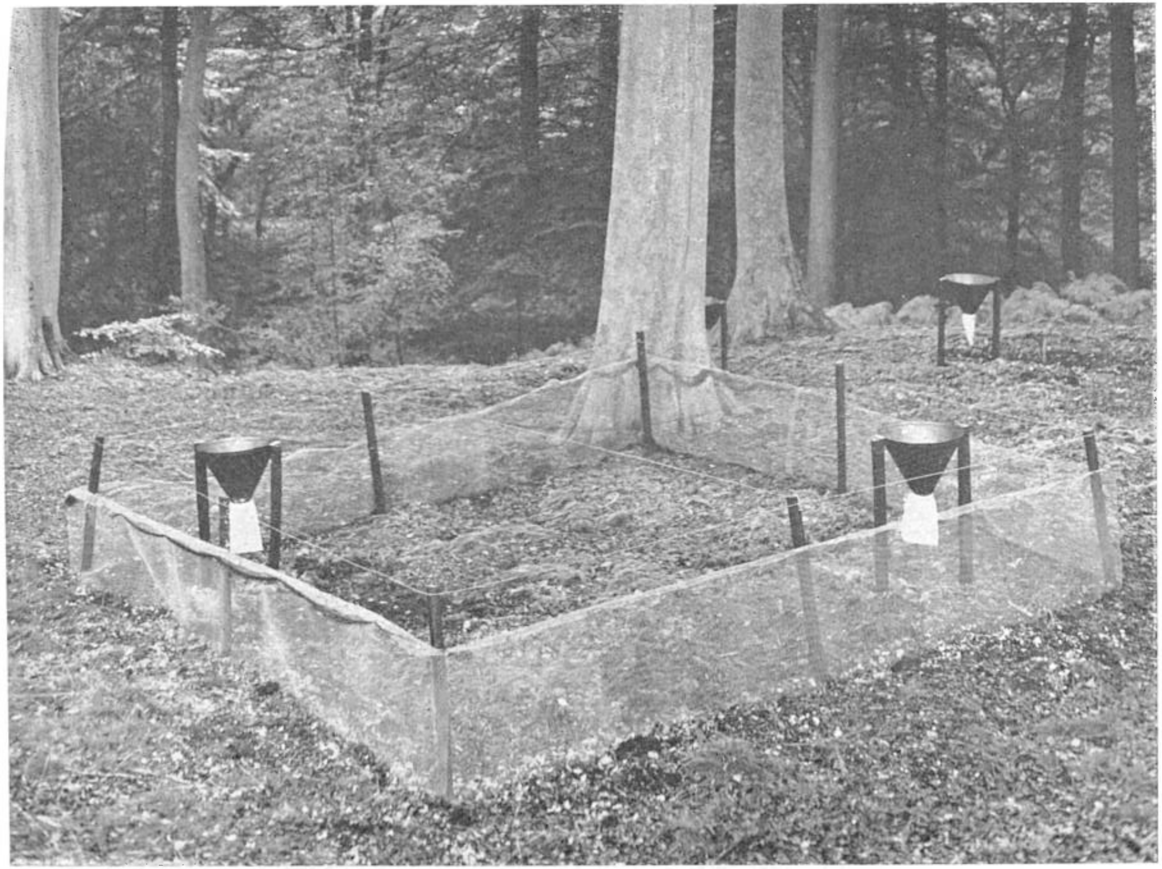

PLATE 3. Rowe; Mammals, and Buscewicz, Seed.

Sampling of beech seed fall, Slindon, Sussex. Protection against rodents provided by $\frac{3}{8}$ inch wire mesh, against pigeons by overhead polythene net (not clearly visible in picture).

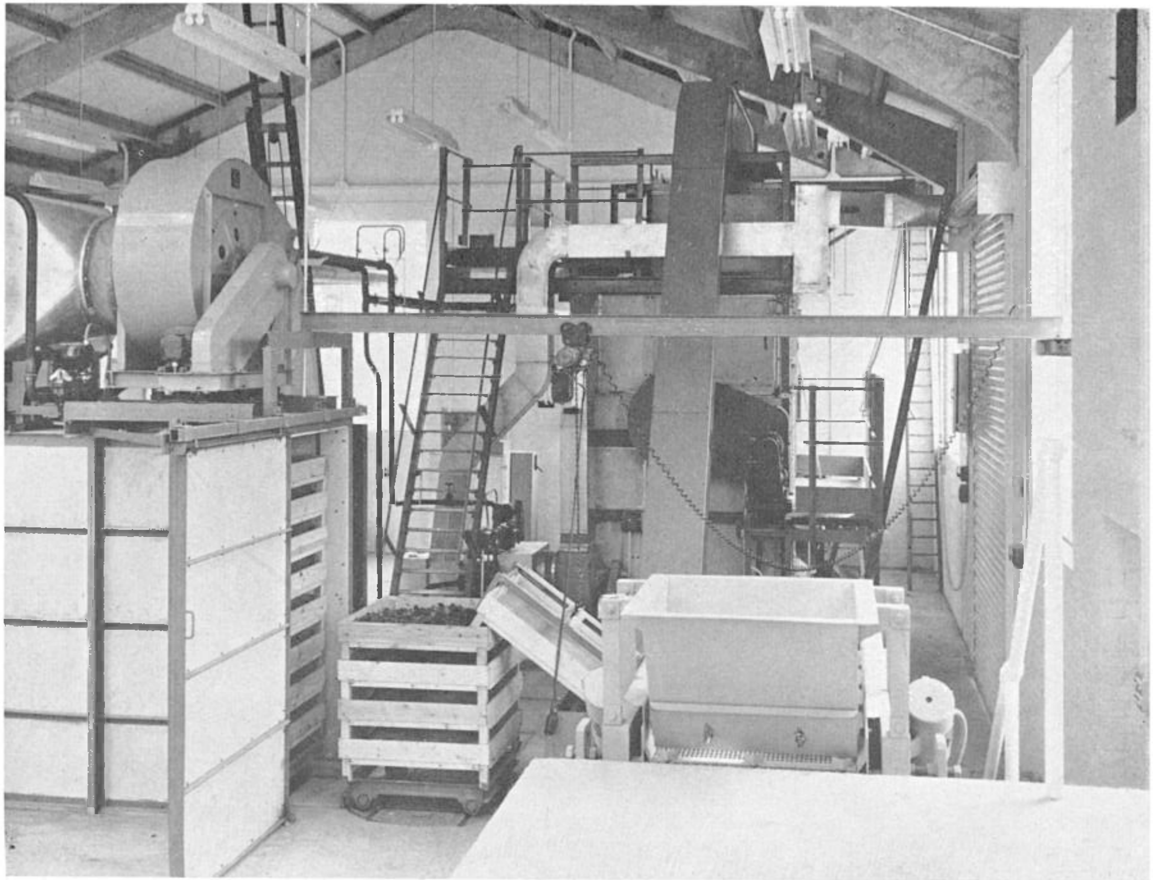

PLATE 4. Buscewicz; Seed.
General view of the new Seed Extraction Plant at Alice Holt; erected 1964.

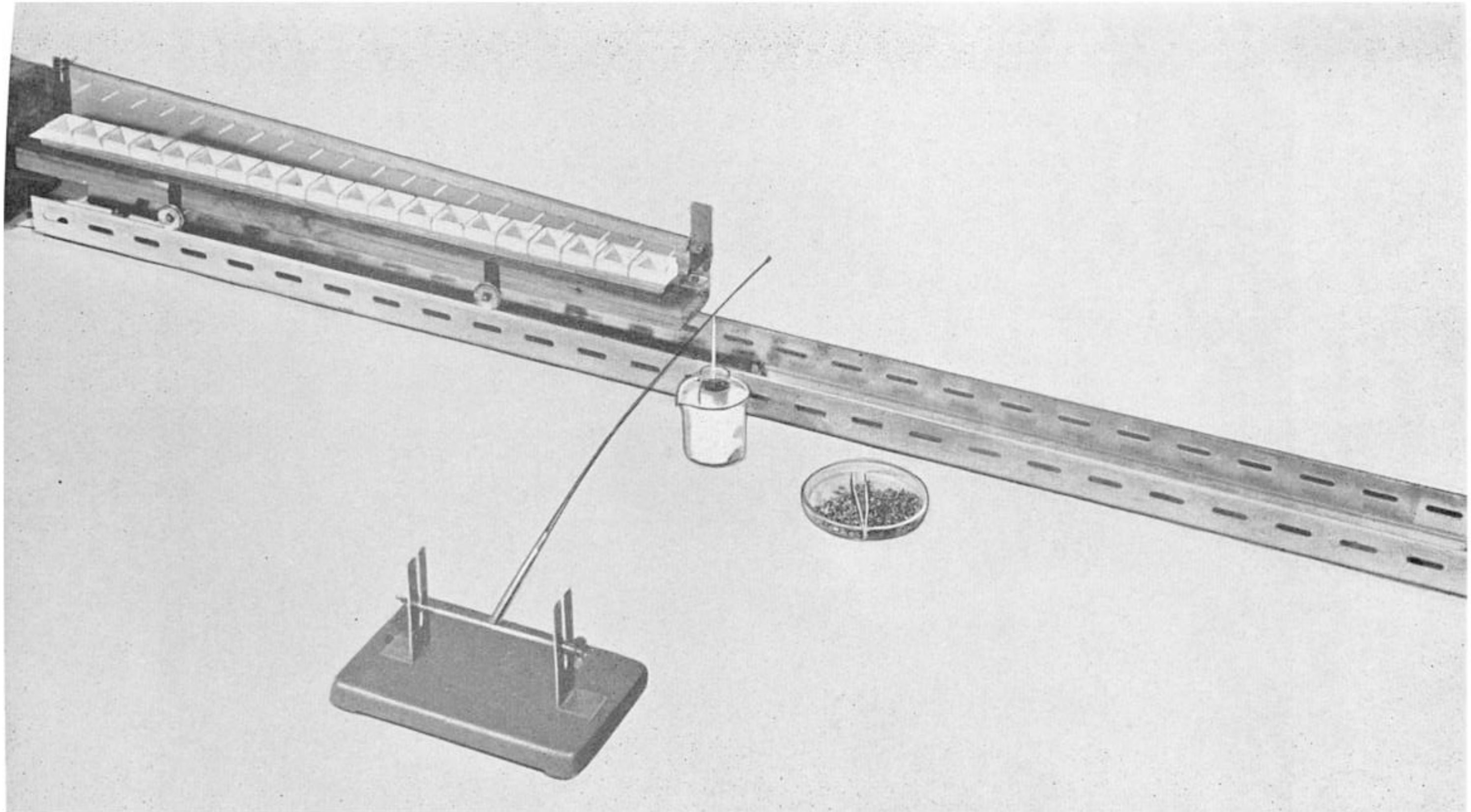

Plate 5 Faulkner et al; Genetics.

Simple device for classifying conifer seeds by weight intervals of ·001 gm. The drawn glass filament in the foreground serves as a "spring-balance," the seed is 'tripped' to the appropriate container on the moving carriage by the stops on the inclined plane. It may be of value in studies of the influence of seed weight on growth, etc.

PLATE 6. Neustein; Artificial Regeneration, also Windthrow.

Work of the Wilder-Rainthorpe Brush Chopper at Forest of Ae, Dumfriesshire. The slash from clear felling thirty-year-old spruce has been sufficiently broken down to permit of direct planting without burning or windrowing. See also Plates 7 & 17–20.

PLATE 7. Neustein; Artificial Regeneration, also Windthrow.

A plot of 0·3 acres at Forest of Ae, three years after planting with Norway and Sitka spruces, and Western hemlock. Note scarcity of weed growth. August 1964. See also Plates 6 & 17–20.

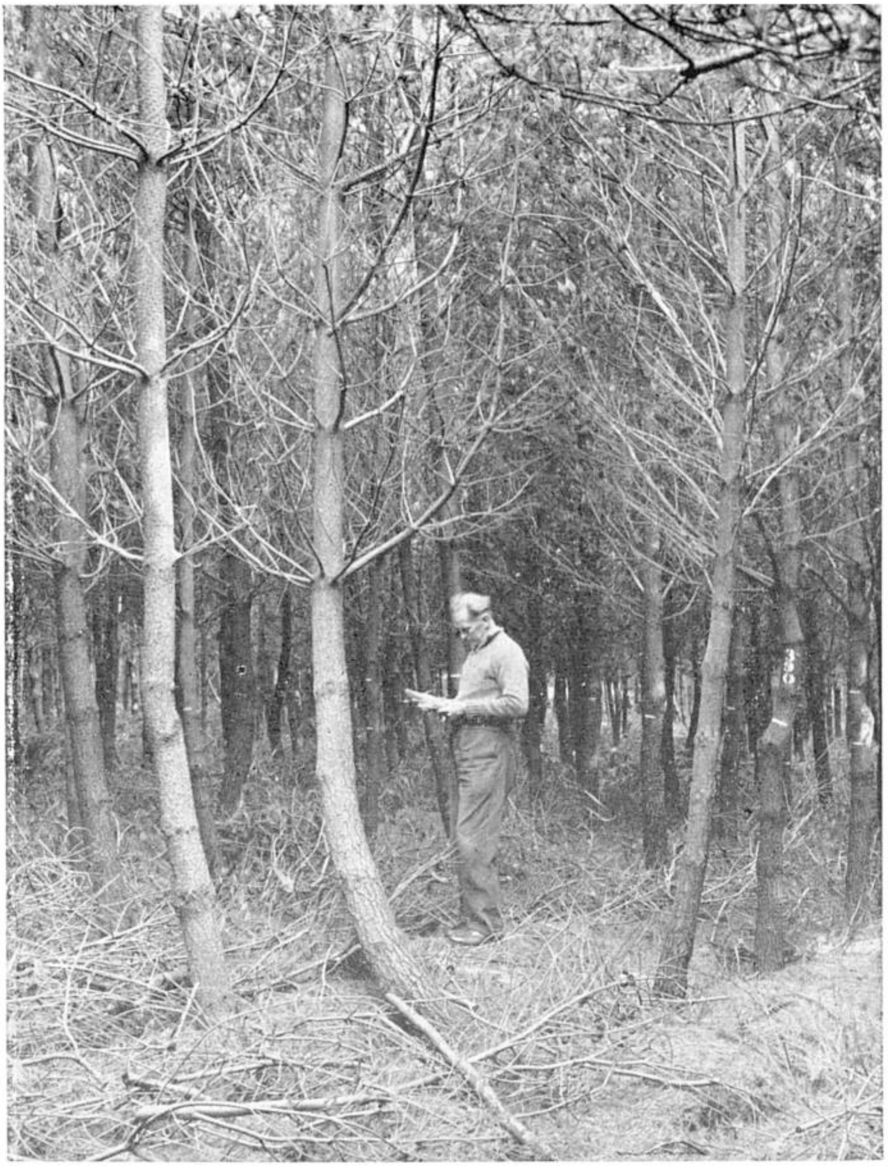

PLATE 8. Lines and Mitchell; Provenance of Lodgepole pine.

Twenty-six-year-old plots in an experiment at Wykeham, Allerston, Yorkshire.

To left (PLATE 8): origin Olympic Peninsula, Washington coast.

To right (Plate 9): origin Prince George, interior of British Columbia.

The Washington coastal material, though vigorous and tolerant of most British conditions, frequently exhibits poor stem form, especially 'basal sweep' (as seen here on the nearest stem) due to instability in the early years. Lodgepole pine from highly continental climates, such as Prince George, usually grows well enough in the east of the country, but is intolerant of the moist exposed conditions of the west.

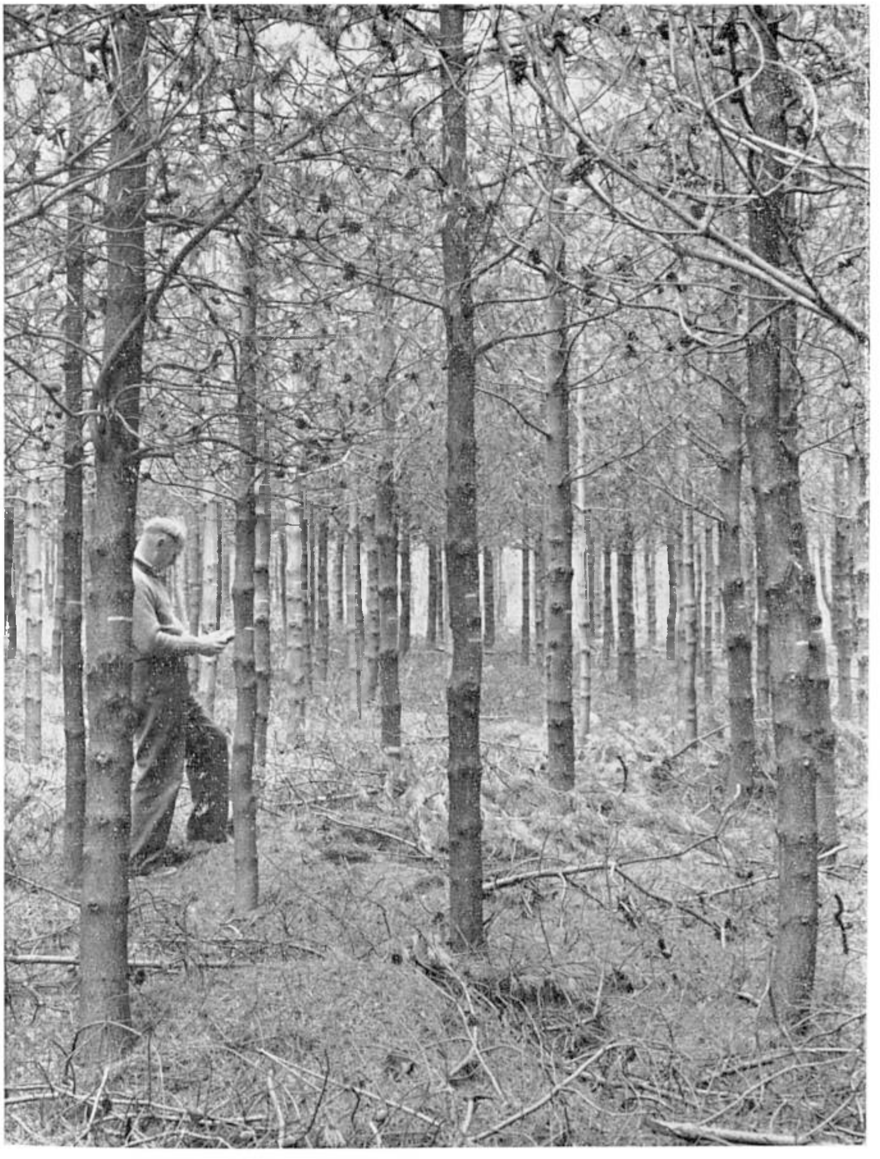

PLATE 9. See PLATE 8 opposite.

PLATE 10. Faulkner et al; Genetics.

A safety harness (the Pakawa Savall; Forestry Commission pattern) developed by the Research Branch to replace existing belts. Full harnesses are recommended by the Medical Officer of the Ministry of Labour Factories Inspectorate. A special feature is the seat strap which can be used with a chain to support the climber whilst in the Tree Bicycle (left), or as a seat for cone collection on descent (right).

PLATE 11. See PLATE 10 opposite.

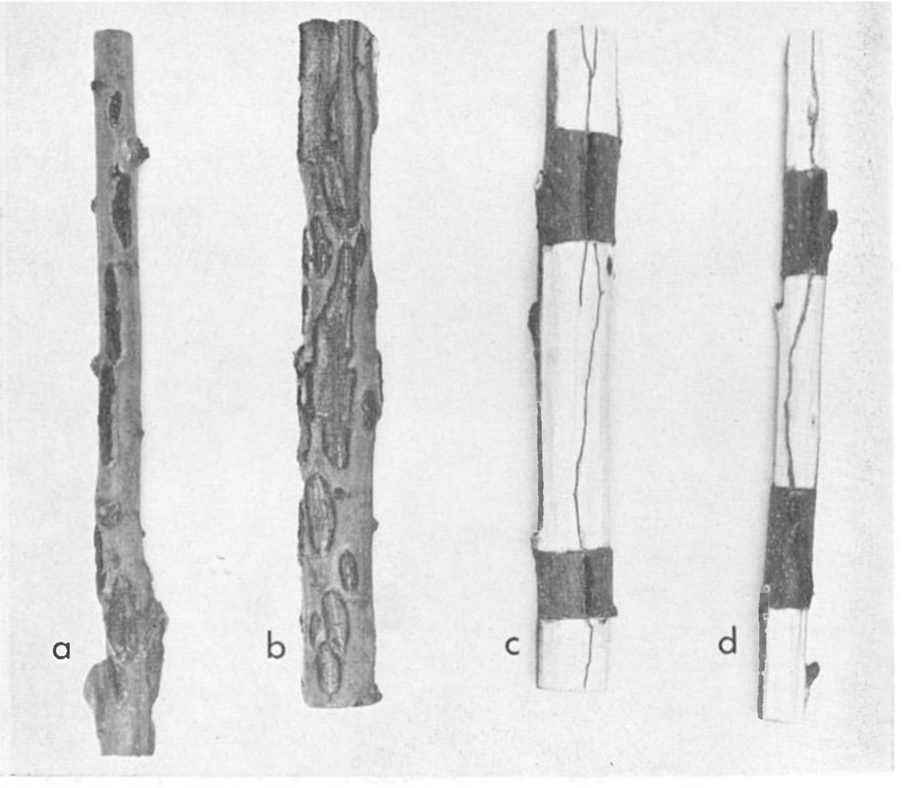

PLATE 12. Jobling and Young; Resistance of Poplar to Canker.

Bacterial Canker of Poplars associated with Agromyzid tunnels. (a) Typical elongated stem cankers. (b) Severe injury on 'very resistant' P. *tacamahaca* × *trichocarpa* 37, despite its ability to recover from attack. (c) Wood cut away to show stained tunnels with associated cankers. (d) Two open cankers and continuous occluded lesions over the course of a tunnel.

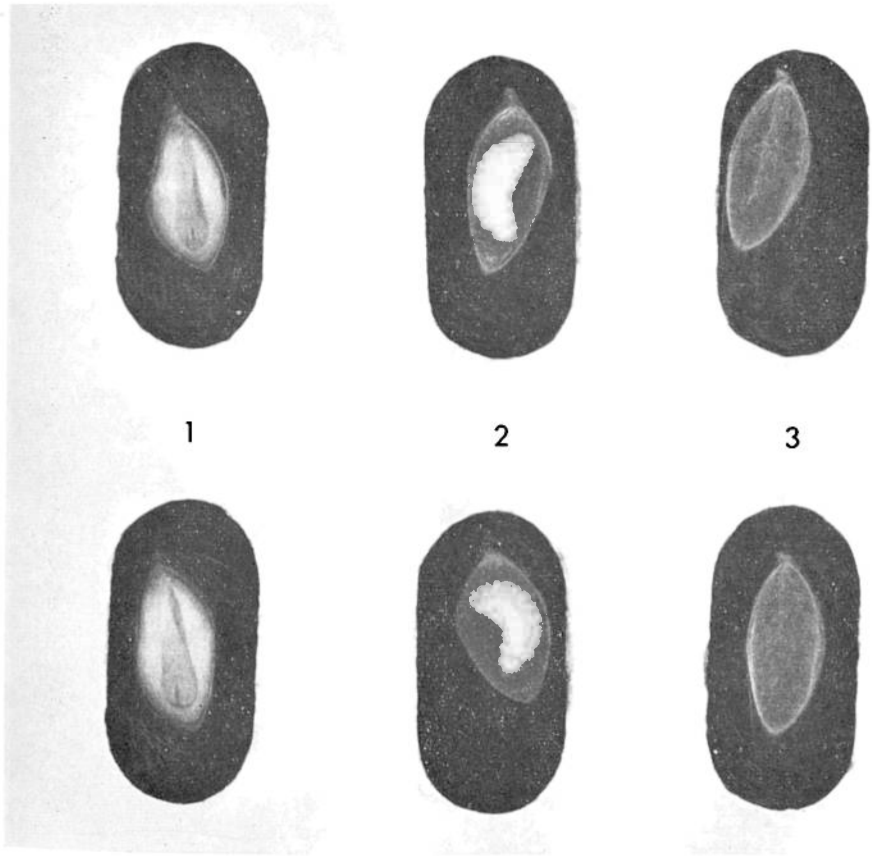

PLATE 13. Bevan; Entomology and Buscewicz; Seed.

Douglas fir seed wasp, *Megastigmus spermotrophus*, investigation.
Part of a radiograph showing: 1. Sound seeds; 2, Seeds containing fully developed larvae; 3. Empty seeds. Radiography is used as a routine method for assessing infestations by this insect.

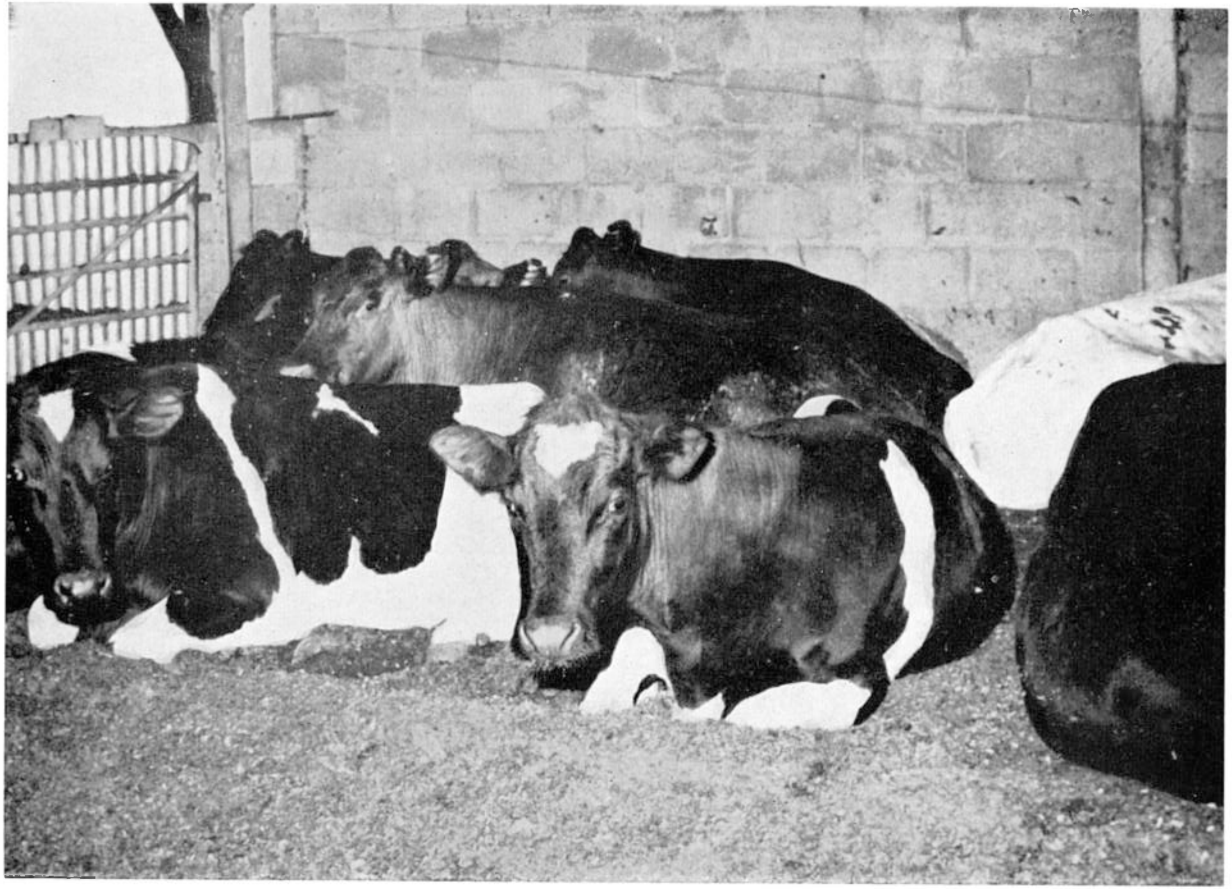

PLATE 14. Holtam; Utilisation Development.

Loose-housed cows on bed of wood flakes.
(Photo. by courtesy of the National Institute for Research in Dairying).

PLATE 15. Jeffers: Design and Analysis of Experiments.
The Sirius computer at Alice Holt.

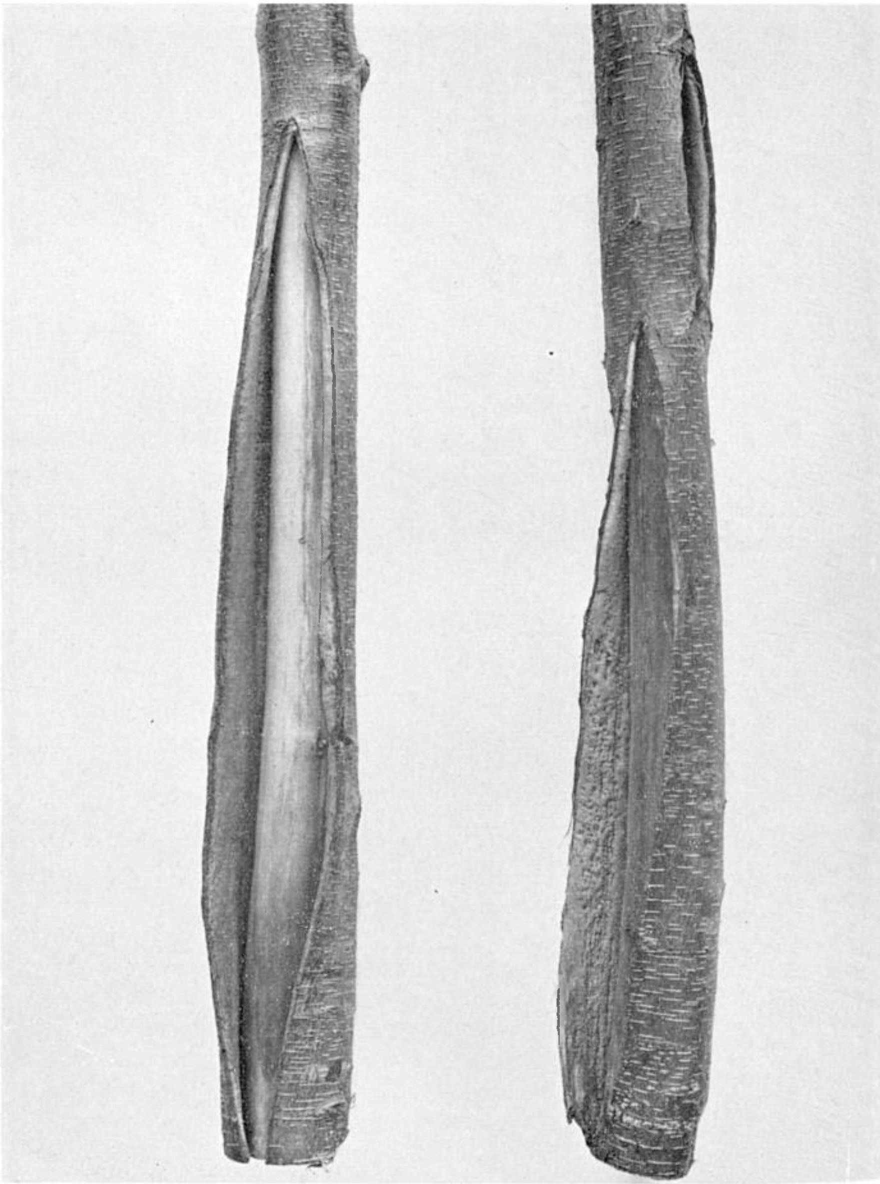

PLATE 16. Nimmo; Winter Damage to Southern beech, *Nothofagus*.

Winter damage to *Nothofagus procera*. The inner bark tissues have not been killed and continue to develop, forming an unsightly canker.

PLATE 17. Neustein; Windthrow, also Artificial Regeneration.
View across a one-acre clearing in the Forest of Ae. For a view of the ten-acre clearing, please see Plates 6, 7 and 18–20.

PLATE 18. Neustein; Windthrow, also Artificial Regeneration.

Aerial view of the Forest of Ae experiment and surrounding country. Scale: 4 inches to 1 mile = 1/15,840. (Royal Air Force photograph. Crown Copyright Reserved).

PLATE 19. Neustein; Windthrow, also Artificial Regeneration.

Aerial view of the experiment, showing (bottom right) the ten-acre clearing, and several smaller ones. All deliberate clearings are outlined by circles. The longer dark lines show (above) the 800 foot contour and (below) the 900 foot contour. Forest of Ae. March 1962. Scale: 6 inches to 1 mile = 1/10,560. (Royal Air Force photograph. Crown Copyright Reserved).

PLATE 20. Neustein; Windthrow, also Artificial Regeneration.
Ten-acre clearing at Forest of Ae three years after chopping and re-planting.
See also Plates 6 and 7.

PLATE 21. Henman; Drainage of Deep Peat.

Flanders Moss, Loch Ard Forest, Scotland. Before draining began a metal pipe was screwed into the clay beneath the peat, as a datum point. The peat depth here is 21 feet.

PLATE 22. Lines and Mitchell; Scots Pine Provenance.

Scots Pine provenance trials at Findon, Black Isle Forest, Scotland.

Foreground : Plot B.13. 26/54. "Rigensis" from Latvia. *Background :* Plot A.13. 25/505. Strath Conon, Ross-shire, Scotland, on right Plot A.14. 26/502. Innes, Morayshire, Scotland, on left.

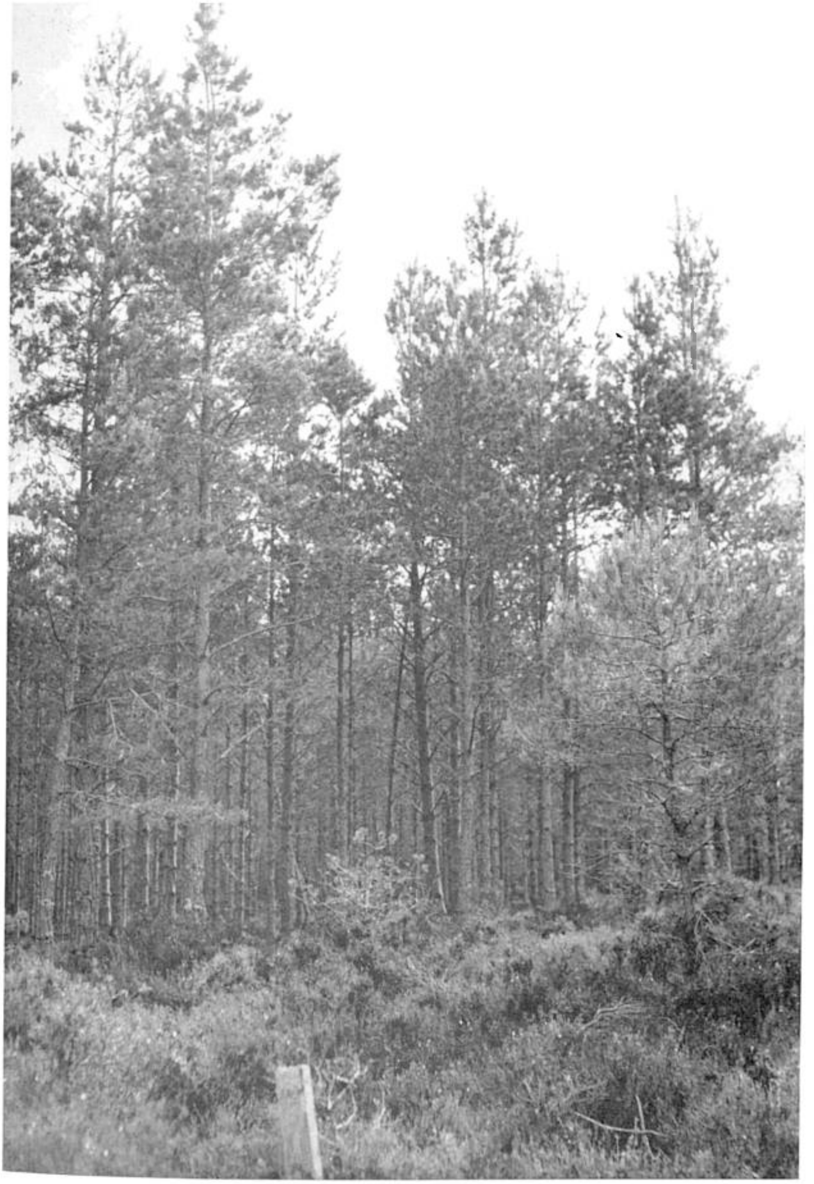

PLATE 23. Lines and Mitchell; Scots Pine Provenance.

Scots Pine provenance trials at Findon, Black Isle Forest, Scotland.

Foreground: Plot B.11. 26/9. Sierra Nevada, Spain. *Background:* Plot A.10. 26/501. Darnaway, Morayshire, Scotland, on right. Plot A.11. 26/17. "East England" on left.

PLATE 24. Henman; Drainage.

Drainage of thicket-stage Sitka Spruce. A Massey-Ferguson hydraulic digger, mounted on the back of a "Long-Wide" County tractor, making drains at Kershope Forest in Cumberland.

A comparison of the amount of hormone in intact and disbudded hardwood cuttings showed no significant differences, although disbudded cuttings form considerably fewer roots than do intact ones. Thus, the stimulatory effect on rooting caused by expanding buds could not be ascribed to increased auxin production, and it seems possible that expanding buds may produce some other factor of a hormonal nature which stimulates rooting.

A study was carried out on the seasonal changes in hormone level in stems taken from a poplar hedge. In March, dormant, leafless shoots were found to contain low levels of the acidic auxin and no detectable neutral auxin. The level of the acidic hormone rose sharply as the buds expanded and high levels were maintained from June to August. With the onset of dormancy and leaf-fall, the hormone levels fell sharply.

Further Observations on Rooting Responses

A comparison was made of the rooting responses of terminal, sub-terminal and basal portions of one-year stool shoots. Thick stool shoots were harvested in October and cut up into the three portions, each cutting being approximately eleven inches in length. Since it had previously been found that a long chilling period had a favourable effect upon the rooting of cuttings of *P. canescens* (*Research Report 1962*, p. 125), a comparison was also made of the effects of a seven-week as against a sixteen-week chilling period. After chilling, both series of cuttings were then maintained for seven weeks at 12°C in a rooting medium. The results are shown in Table 20, from which it will be seen that sixteen weeks chilling resulted in a poorer rooting response than did seven weeks. Further, it is seen that terminal and sub-terminal cuttings produced higher numbers of roots than did basal cuttings.

Table 20

EFFECT OF TYPE OF CUTTING AND LENGTH OF CHILLING PERIOD ON ROOTING OF POPULUS ROBUSTA

Chilling period	Terminal cuttings		Sub-terminal cuttings		Basal cuttings	
	% rooted	Mean No. of Roots	% rooted	Mean No. of Roots	% rooted	Mean No. of Roots
7 weeks	100	12·1	100	11·7	93	5·7
16 weeks	100	11·8	100	8·7	70	2·9

An experiment was carried out to determine the effect of planting date on the subsequent rooting response of hardwood poplar cuttings. Cuttings were taken at regular intervals from October to March, and were planted out-of-doors alongside the source plants until the last sample had been collected, so that the temperature conditions were the same for all samples. After the last sample had been collected all cuttings were transferred to a temperature of 20°C in darkness, for observations on the rooting response. As is well-known, root initials are laid down in the stem in late summer and these will readily emerge as "stem roots" after chilling. As expected, the mean number of such stem roots per cutting was not affected by the date of collection. On the other hand, the mear number of roots formed near the basal cut or within 3 mm. of it ("wound roots") increased steadily throughout the season. Thus, from the results of this experiment it would seem that better rooting responses are obtained by delaying the date of collection.

Summary

A study of the endogenous hormones of *Populus* 'Robusta' has been carried out with special reference to the rooting of leafy and hardwood cuttings. Both acidic and neutral auxins are found to be present in the shoot of this species. The hormones accumulate in the basal region of leafy cuttings within five days of planting, there being higher levels of hormone in actively-growing than in dormant cuttings. The level of the acidic hormone also increases markedly in hardwood cuttings during the first few days after planting under warm conditions, and the amount of hormone is not reduced by disbudding. The seasonal changes in hormone level were followed in the shoots of a poplar hedge.

In further studies on the rooting of hardwood cuttings, it was found that larger numbers of roots were obtained from terminal and sub-terminal cuttings than from basal cuttings. An experiment to determine the effect of the date of collection of hardwood cuttings indicated that better rooting was obtained by delaying the date of collection. Chilling of hardwood cuttings for sixteen weeks resulted in lower root numbers than chilling for seven weeks.

STUDIES ON TIT AND PINE LOOPER MOTH POPULATIONS AT CULBIN FOREST

By MYLES CROOKE
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During 1963 investigation was continued along the lines described in some detail in the 1963 *Report*. The present account is in the nature of an interim statement. Culbin Forest is situated in Morayshire, Scotland.

Pine Looper Pupal Densities

The intensity of winter sampling for Pine looper pupae was increased by doubling the number of quarter square yard quadrats to ten on each of the eight transects in Plot 1 and the six in Plot 2. In 1963 Pine looper densities throughout the forest fell far below those obtaining in 1962, and this general trend was reflected in the figures obtained from the study plots. In Plot 1 the mean density was 0·15 pupae per square yard (1962, 3·5 pupae per square yard) and in Plot 2 the mean was 0·13 pupae per square yard (1962, 4·3 pupae per square yard).

Tit Numbers

Study was concentrated on the Coal tit, *P. ater*, since the Crested tit, *P. cristatus*, does not readily breed in nesting boxes and there seems therefore to be no chance of substantially increasing its numbers in the boxed Plot 1, as opposed to the control Plot 2. In the case of the Coal tit, estimates of the numbers of breeding pairs per plot were attempted, firstly, by plotting the positions of singing males and thus defining the positions of occupied territories and, secondly, by counting the numbers of family parties encountered in the plots after the young had left the nest.

The first method, as in 1962, yielded remarkably few contacts for the time spent on observation, and this made interpretation of the results somewhat difficult and unreliable. In each plot the distribution of singing positions suggested that there were six occupied territories.

On the 14th June, 1963, search was made for family groups of Coal tits. A team of seven observers walked in line through each compartment in the two plots and located eleven family parties in Plot 1, and eight such groups in Plot 2.

It appears, therefore, that in 1963 the numbers of breeding pairs on the two plots were about equal, with the estimates based on the detection of family parties giving a higher figure than those based on the mapping of territories. This is essentially the situation which obtained in 1962, although in that year the overall population levels were somewhat lower than in 1963. That estimates based on counting family parties are probably more reliable than those derived from the territories in a forest where singing is so infrequent, is indicated by the fact that, in Plot 1, ten nests were observed in 1963. Six of these were situated in the artificial nest boxes erected in September 1962 and four occurred in natural sites.

Breeding Biology of the Coal tit P. ater.

The occupation by Coal tits of six nest boxes in 1963 allowed of observations being made on the breeding biology of this bird at Culbin. Information was collected on such points as the times of nest-building, egg-laying, hatching, and departure from the nest, on clutch size and on survival. The main point of practical import is that the young are off the nest well in advance of the period of peak emergence of the Pine Looper moth, *Bupalus piniarius*—e.g. five out of six nests empty by 6th June: peak emergence of *B. piniarius* in third week of June—so that, for the purposes of this particular study, it becomes vital to ascertain for how long after leaving the nest the family remains in its near vicinity. It is planned to investigate this point in 1964.

Nest Boxes

A further one hundred John Gibb type nest boxes were placed in Plot 1 in February, 1963.

Summary

The collection of concurrent pine looper moth and tit population density indices continued in two 200-acre plots at Culbin Forest in 1963. In both plots, pine looper pupal densities were much lower than in 1962, averaging only 0·15 pupae per square yard in Plot 1 and 0·13 pupae per square yard in Plot 2. Numbers of breeding pairs of Coal tits increased somewhat, to between 8 and 10 pairs per plot, despite the severe winter. The provision of artificial nest boxes in Plot 1 has not produced a breeding population greatly different in size from that in Plot 2, without nest boxes; but occupation of the artificial nest sites has permitted the collection of data on the breeding biology of Coal tits.

MEASUREMENT OF LIGHT INTENSITY

By W. A. FAIRBAIRN
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The investigation of the light regimes in Norway spruce and Silver fir was divided into three parts:

(1) The growth of seedlings under different filters.

(2) Light measurement in forest stands.

(3) The growth of natural regeneration.

Two separate nursery trials were initiated during the year with seeds of the two species supplied by the Forestry Commission. The seeds were first sown in June, 1963, in small boxes covered with infra-red and ultra-violet filters and with perspex and with ordinary glass. The second series of seeds were sown in October and the seedlings are now beginning to appear. A third series of seeds brought from the French Jura are now being sown. Measurements of growth rates under the different media are made.

Light intensity measurements were made under different grades of thinnings in Norway spruce in the Forest of Ae, and will be repeated in the coming year; some measurements were also begun in Silver fir stands at Corrour Estate in South-west Inverness-shire, and these too, will be continued.

The opportunity was taken of examining natural regeneration of each species in the French Jura and in the Vosges during a recent forestry tour; young plants and seedlings of each species were brought back for laboratory examination.

Three light integrators were purchased during the year, after examination and trial of the equipment in the field. The measurement of the light regimes in different stands, with special reference to Norway spruce and to Silver fir, will be continued during the coming growing season.

ECONOMIC EVALUATION OF RECREATION IN MULTIPLE-USE FOREST

By W. E. S. MUTCH
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Research and experience in silviculture and mensuration should allow, in theory, a continual refinement of forestry techniques towards the procedure of maximum production for each site. It is clear, however, that in many British forests, perhaps in most, foresters commonly will be denied the unhindered use of those techniques which yield the highest woody production or the best financial result. Restrictions, some imposed, others induced by public demand, are likely to cause departures from the 'best course' of management, where this last phrase has a narrow timber-revenue implication.

The demand for public outdoor recreation is now commonly cited as a factor likely to cause a divergence of forest management from the financially most rewarding procedure aimed at a single product. Numerous papers have been written about the level of this demand in North America, some giving quantitative data, but for Britain there is general lack of information on the current level of demand, on the trend of demand, and even on what, precisely, is demanded. While these are unknown, discussion of the impact of public recreation on forest management is liable to be ill-founded and premature.

Early in 1963 it was decided to study recreation as one of the group of benefits which forests commonly afford without a financial return. Public recreation is likely to be an important factor influencing management decisions in British forestry. Evaluation of the benefit may assist in rationalising new forest investment and in managing existing stands for the highest aggregate multiple-use return.

A pilot survey was made in the New Forest on selected days in August 1963. A casual sample was taken of groups of people in the forest, information being sought by interview, using a type of market-survey questionnaire. The limited objectives on this occasion were to develop an acceptable questionnaire and field procedure, and, with the answers collected, to find data-processing methods appropriate to such studies. The field workers were university students.

Information was gathered by interview from nearly 600 groups, representing about 2,400 individuals. A very small number of people refused to co-operate, less than 1 per cent, and it was clear that a longer questionnaire could be used, providing more precise information and better statistical control. An improved form has now been written.

Punch-card processing was chosen for working up the data, and the analyses are now in hand. The pilot survey provided some useful information on the tourist use of the New Forest, although the sampling method, imposed by the road network and the desire to minimise expenditure in the development stage, limited the conclusions that might be drawn.

It is intended that the improved questionnaire should be used to investigate the level and form of the recreation use both in traditional tourist areas, such as the Cairngorms, and in the forests near industrial towns, in which forest recreation demand reputedly is growing.

PART III

Reviews of Continuing Projects, Interim Reports, Methodology, etc.

THE FORESTRY COMMISSION LIBRARY: A REVIEW

By H. L. EDLIN

Historical

The Forestry Commission Library had its origin in a collection of books on woodland subjects which was begun by the Board of Agriculture (now the Ministry of Agriculture, Fisheries and Food) in 1889. In 1919 this was transferred to the newly-formed Forestry Commission and maintained at its headquarters in London until 1939. Early growth was slow, however, for the Commission's Research Branch, then a small affair, was able to draw on the Library resources of the Commonwealth Forestry Institute, at Oxford, for most of its needs.

In 1939 the Library was evacuated to the Commission's wartime headquarters in Bristol; this proved a fortunate move as its previous home in London was severely damaged by wartime bombing. In 1946, the decision was taken to set up the Research Station at Alice Holt Lodge, near Farnham, some forty miles south-west of London. A library on the spot was essential, and the existing collection was transferred from Bristol to form its nucleus. Under Mr. G. D. Kitchingman, Librarian from 1946 to 1960, and Mr. R. G. Semple, between 1960 and 1963, steady expansion took place to meet increasing needs.

The Library is designed to serve all grades and professions in the Commission's service, including its Research Branch, and also to be available for reference purposes to a wider public concerned with forest science.

Accommodation

The Library is conveniently housed in three rooms forming the south wing of a country house, set amid fields yet surrounded by woodlands. The modern laboratories occupy an adjacent block nearby. Enquirers enter by the central 'Control Room' where the staff have their desks. To one side of this there is a large 'Periodicals' room occupied by:

(a) Periodicals.

(b) 'Information Files' for items that do not form part of any series, but are too slender to bind as books.

(c) Reference Catalogues maintained on a card index basis.

On the opposite side of the Control Room, another room, the 'Bound Books Room' holds the bound books, and also study tables for readers, sited here because it is quiet. There is also, in another part of the building, a 'Stack Room' used to store old runs of periodicals, many of them on the fringe of forest science or in little-used languages, which are seldom consulted.

Satellite Collections

Besides the main collection housed in the Library itself, each Section of the Research Branch holds a small satellite collection of books needed for its immediate tasks. All these, however, are purchased by the main Library and catalogued by it, and can be recalled for other readers as occasion requires.

The Reference System

The Oxford System of Decimal Classification for Forestry, devised by the Commonwealth Forestry Bureau, is employed throughout. There have been a few minor variations from its scheme of arrangement, but even these few have since been regretted! In practice, the full list of Card Index Classification numbers provided by the Bureau proves, in many instances, to be too complex for our needs. It is a simple matter to abbreviate the full Oxford sets of numbers, and where necessary to add to or amend each group, without departing from the main scheme.

Full use is made of the Index Cards supplied by the Bureau, at weekly intervals, in advance of the publication of 'Forestry Abstracts'. These enable the Librarian to pin-point the more significant papers almost as soon as they have appeared. To do so, it is necessary to take a full set of cards, including those on timber utilisation, even though only a fraction of the references have much bearing on the Commission's work. With this digest of current literature at hand, most significant publications can be traced: although the searcher must always be alert to the chance that something may have slipped through the Oxford net, it is seldom a really big fish.

As a Government library we have also to keep track of official publications, and this is done by means of the Daily Lists issued by Her Majesty's Stationery Office. These lists also include the publications of the United Nations Organisation and related bodies.

Shelving Arrangements

Bound books and 'Information' items are shelved or filed according to their Oxford Decimal Classification. Periodicals are shelved by country of origin, and, within each country, by titles ranged alphabetically.

Languages and Translations

The bulk of the literature is naturally in English, or has English summaries. The second most important language is German, which maintains its world lead in certain specialised fields such as Forest Entomology and Forest Pathology. The Scandinavian languages rank next in their significance for British forestry. A useful proportion of the Research staff can follow technical articles in one or another of the Germanic or Romance languages, particularly where photographs, diagrams and tables present the gist of the matter. For all other languages we are largely dependent on the abstracting services of the Commonwealth Forestry Bureau, for our first appreciation of the subject matter. Translations are regularly made of significant articles, but translation is always expensive. As a simple comparison, the translation of a single article often costs as much as the purchase of a textbook ten times as long. But the article may well contain information of immediate practical application that will not appear in text book form for several years, if ever. Some economy is achieved through the 'pooling' of translations with related libraries, under the Commonwealth Translation Exchange Scheme.

Exchanges

The greater part of our periodicals and series are obtained by exchange with other forestry, agriculture, or timber research organisations, mainly overseas.

Our experience is that the exchange system brings in most of what we need at reasonable cost and the minimum of delay. We only exchange with organisations such as forest research stations, forestry departments and scientific societies, not with individual workers. The needs of the individual investigator, which are more specialised, can usually be met by the issue of a reprint or a few short publications in his own field.

The Scope of the Library

The central theme is simply:

(a) Forestry in the British Isles. This brings in three related fields, namely:

(b) Forestry in Northern Europe.

(c) Forestry topics from any country that have a bearing on British forest practice.

(d) Related sciences and industries; these form an exceptionally wide range, from basic physical and biological sciences to the techniques of timber use and road construction.

In practice, the only workable scheme is to maintain as full a coverage as possible over the main British forestry field, with a 'useful' coverage of other topics. We have to rely upon other associated libraries for detailed coverage, particularly in the periodicals field.

Relations with Other Libraries

Fortunately we are well placed, both geographically and by virtue of co-operative arrangements, to draw upon the resources of associated specialised libraries. In particular, we can get help from, or refer enquirers to, the Libraries of the Commonwealth Forestry Institute, the Forest Products Research Laboratory, the Nature Conservancy, and the Ministry of Agriculture—all within daily travelling distance.

Special Collections

Three special collections are maintained on the basis of complete coverage insofar as funds and availability of copies allow:

(a) Textbooks on British forestry and British forests, ancient and modern.

(b) Textbooks, published within Britain, on trees and their cultivation within the British Isles, including both native and introduced kinds.

(c) British forestry periodicals, from the earliest available issues onwards.

It is hoped to establish a leading position in this field, but a few items (including one rarity priced at £300!) lie beyond our means.

Library Policy

The general aim is to maintain a flexible outlook over the whole field of forest science. Emphases are continually changing. New subjects frequently come within our sphere, whereas old ones may lose their erstwhile importance. In any one research organisation, really original work is only likely to be taking place in half-a-dozen directions. But the Librarian must be on the look out for new developments occurring in any one of several hundred research stations all over the world. He will seldom be the first, among the staff of his own organisation, to hear of the new idea; in practice specialist workers in each field will usually have first news of fresh discoveries through their correspondence and meetings with others engaged on the same subjects. But he should be the first to notice it as soon as papers start to appear in the literature. So he must be prepared to take a wide view over everything that is being published, and to direct attention towards new fields promptly.

As a practical instance of a subject suddenly acquiring prominence, the harmful side-effects of insecticide, fungicide, and herbicide residues have occupied much of our attention recently. This subject has given rise to scores of scientific papers, two Government reports, a new periodical entitled *Residue Reviews* and the popular book *Silent Spring*, by the late Rachel Carson, all within the space of twelve months.

No-one can say which field of knowledge will next increase in importance in this way. Therefore, besides amassing a vast literature on well-worn forestry topics such as mensuration, we aim to keep a small, but well diversified, range of papers and references covering 'minor' and 'fringe' topics that may at any time become major ones.

CYCLOHEXIMIDE FUNGICIDE TRIALS AGAINST DIDYMASCELLA THUJINA ON WESTERN RED CEDAR, THUJA PLICATA

By R. G. PAWSEY

Introduction

Needle infection of Western red cedar, *Thuja plicata*, by *Didymascella* (*Keithia*) *thujina* (Durand) Maire was first recorded in the British Isles in 1919 in Ireland (Pethybridge 1919); in the same year it was also recorded in Sussex, England (Loder 1919). Since then the disease (commonly known as Leaf blight, or *Keithia* disease, after the former generic name of the fungus) has become widespread on Western red cedar throughout Britain, often causing severe damage to nursery stock, but also occurring frequently on older trees, on which the damage is considered of little importance.

Soon after the establishment of the Pathology Section at the Forest Research Station at Alice Holt in 1946, fungicidal field trials were started in which, over a number of years, a wide range of commonly-used fungicides was tested against infection by *D. thujina*. The results of these experiments were extremely disappointing, and although in some experiments certain copper fungicides appeared to reduce infection slightly, no fungicide tested was considered effective enough to warrant recommendation for general use against the disease. In view of these results, changes in the usual practice of raising *Thuja* planting stock were tried to prevent or minimise the establishment of the disease in nurseries. This led to the raising of *Thuja* in 'isolated' nurseries, described by Peace (1958), and later to the nursery rotation scheme described by Pawsey (1962), which is currently practised for the production of nearly all Forestry Commission *Thuja* planting stock. However, although the rotation scheme substantially reduces the risk of infection in suitable nurseries, there is still an urgent need for an effective fungicidal treatment against *D. thujina*, particularly in private forestry where nursery rotation is generally not practicable.

Initial Trials with Cycloheximide Fungicides

In recent years the antibiotic substance cycloheximide and some of its derivatives have been shown to be effective against a number of diseases caused by obligate parasitic fungi, notably rusts and powdery mildews. In American forestry, large-scale forest application of Actidione BR (a proprietary liquid formulation of cycloheximide) has been carried out against White pine blister rust, *Cronartium ribicola*, on *Pinus strobus*. From 1960 onwards, a series of nursery trials was carried out to test the effectiveness of cycloheximide and its derivatives against *Didymascella thujina* on *Thuja plicata* under British conditions.

Initial trials in the summer of 1960 were started at Alice Holt to observe the phytotoxic effect of Actidione BR and the oxime, acetate and semicarbazone derivatives of cycloheximide on two-year-old seedlings of *T. plicata*. Each material was applied at 50 and 150 ppm. at a rate of 150 ml. per sq. yd. in a four block randomised plot experiment with plots of two square yards. Within a month of spray application, moderate to severe foliage and shoot-tip browning was caused by both concentrations of Actidione BR, but none of the other treatments caused any phytotoxic symptoms. A further application, at the same concentration, of all materials was made in September 1960, with the intention of recording the incidence of natural infection in the following spring on transplants taken from the original seedling plots. However, before the stock was transplanted in November, slight infection was observed in the seedbed plots and careful examination showed that infection of low intensity, which was probably present before the first treatment in July, was irregularly distributed throughout the experiment. There appeared to be no correlation between the incidence of infection and the various treatments applied. In an adjacent part of the same nursery, one-square-yard plots of transplants were established from each original seedbed plot, and infection assessment was carried out in these plots at the beginning of June 1961. Mortality following transplanting of the plants treated with Actidione BR, at both concentrations, was markedly higher than of plants treated with the other materials, and of the untreated controls. There was little difference in survival in the plots treated with the three cycloheximide derivatives and the untreated control plots. In all four control plots active infection by *D. thujina* was observed. In the other plots, fresh infection was recorded only on one of those treated with semicarbazone at 50 ppm, although the apothecial lesions of the previous year's infection were commonly seen. Because observations on phytotoxicity and infection were of an empirical and not of a numerical nature, the results of this first experiment at Alice Holt were not analysed statistically. The conduct of the experiment had been modified as new observations were made, but although very unsatisfactory in many ways, the results indicated that cycloheximide and its derivatives might exert effective control of *Didymascella* infection on *Thuja* nursery stock.

Further Cycloheximide Spraying Experiments

A follow-up of the initial experiment at Alice Holt was started in Sugar Hill Research Nursery, Wareham, in the autumn of 1960. There existed there at that time a block of two-square-yard (3 ft. × 6 ft.) seedbed plots of *Thuja plicata* which had become heavily infected by *Didymascella* in the second year of growth. Before the experiment was started the seedbed plots had received only normal nursery treatments and had not been subject to fungicidal treatments of any kind. The intensity of infection was apparently very uniform through the whole seedbed area.

A group of ten of the original plots was selected for a cycloheximide spray trial. These ten two-square-yard plots were subdivided into bands of seedlings 3 ft. long by 1 ft. wide by cutting out six-inch swathes of seedlings. These bands of seedlings were grouped into four new experiment blocks for the purpose of spray application. Each block contained ten treatment plots: one each of 'Actidione BR' and the oxime, acetate and semicarbazone derivatives, at 50 and 150 ppm., and two untreated control plots. The plots were treated on 8th November, 1960. Polythene screens were erected round the plots during spraying and each material was applied at 40 ml./sq. ft., i.e., 120 ml. per plot. The seedlings were lifted in February 1961, and the plants transplanted into a four block randomised plot layout; the transplant plots being two square yards in size, and the identification of each plot being carried over from the original seedbed layout. On 23rd March, 1961, each of the two-square-yard plots was split into two separate yard-square sub-plots, one sub-plot receiving a further application of the material applied to the original seedbed plot and at the same concentration. The rate of application was 300 ml./sq. yd. An assessment for infection by *D. thujina* was made on 31st May.

Conditions at lining-out were not good, and with stock severely weakened by infection mortality was high. But a mortality count showed that there was no significant difference in survival between any of the treatments, although in the plots treated with 'Actidione BR', at both concentrations, there was a marked reduction in live foliage on plants that were not completely dead. Because of the condition of the plants it was considered impractical to make a strictly numerical assessment of fresh infection lesions. The method of scoring and the treatment code are given in Table 21, and the results of the experiment are set out in Table 22.

These results indicated that the single application of materials to the seedbed plots in November had no effect on the development of infection in the following spring. The further application of materials in March to the transplants appeared to exert a very considerable control effect on infection. In previous studies of the infection biology of *D. thujina* (Pawsey 1960) it was observed that most of the infection developing on *Thuja* nursery stock in the spring resulted from the overwintering of ascospores on the surface of the foliage, although some spring infection may originate from mycelium which remains

Table 21

SUGAR HILL EXPERIMENT, 1960–61
ASSESSMENT SCORING AND TREATMENT CODE

Score	Type	Description
1	Heavy fresh infection .	Abundant new browning symptoms, with apothecial pustules and apothecia with broken epidermis
2	Fresh infection .	Considerable browning of leaflets. Pustule stage frequent.
3	Some fresh infection	Some browning symptoms (most not *Didymascella*) with apothecial pustules infrequent or rare.
4	Little fresh infection .	Browning symptoms present (not necessarily *Didymascella*) but no pustules seen.
5	No fresh infection	No fresh symptoms.

TREATMENT CODE:

	50 ppm.	150 ppm.
Actidione BR .	A1	A2
Oxime . .	B1	B2
Acetate . .	C1	C2
Semicarbazone .	D1	D2
Controls . .	O	O[1]

Table 22

SUGAR HILL EXPERIMENT, 1960–61
RESULTS (SCORING AND TREATMENT CODE AS IN TABLE 21)
ONE TREATMENT (8TH NOVEMBER, 1960)

Treatment:		O	O[1]	A1	A2	B1	B2	C1	C2	D1	D2
Block	I	2	2	2	2	2	2	2	2	2	2
	II	1	1	2	2	3	2	2	2	2	2
	III	2	2	2	2	2	2	2	2	2	2
	IV	2	2	2	2	2	2	1	2	1	2
		7	7	8	8	9	8	7	8	7	8

TWO TREATMENTS (8TH NOVEMBER, 1960 AND 23RD MARCH, 1961)

Treatment:		O	O[1]	A1	A2	B1	B2	C1	C2	D1	D2
Block	I	2	2	4	4	4	4	4	3	4	4
	II	2	1	4	4	4	3	3	4	4	4
	III	2	1	4	4	3	4	3	4	3	4
	IV	2	2	4	4	3	4	4	4	3	2*
		8	6	16	16	14	15	14	15	14	14

*There was some doubt whether the D2 treatment had been applied in Block IV in March, as there was no difference in the appearance in two sub-plots which was in marked contrast to the other plots receiving this material.

dormant in the leaf tissue through the winter. It is thought that the marked difference in control effect between November and March application of the fungicides used resulted from the effectiveness of the March application on young stages of germination of the overwintered ascospores. At the time of November application, the ascospores on the surface of foliage would be dormant, with high resistance to fungicides. The ineffectiveness of the November treatment indicated that any systemic effect of cycloheximide, which has been described frequently in the literature, was short-lived, if it occurred at all. It is thought that under the conditions of the experiment, the effectiveness of March treatments was entirely due to surface protective action of the fungicides. The results of this experiment have been published previously in very brief form (Pawsey 1962 a).

In the experiments described above, 'Actidione BR' was in the form of a liquid concentrate marketed in North America for use on bark against *Cronartium ribicola.* For foliar application on *Thuja*, the concentrate was diluted to the appropriate concentration with a 5% white oil emulsion prepared by Boots Pure Drug Co. The oxime, acetate and semicarbazone derivatives were in crystalline form, the sprays being prepared by dissolving the crystals in a little dimethyl acetamide followed by further dilution with water.

An Examination of the Effect of Different Concentrations and Times of Application of Cycloheximide Fungicides on Disease Development

In 1962, more extensive experiments were carried out in Alice Holt and Sugar Hill nurseries to compare the effectiveness of different rates and times of application of commercial forms of cycloheximide fungicides against *Didymascella* infection. The materials used were 'Actidione BR', 'Actispray' and semicarbazone 1% wettable powder.

(i) Effect of Concentration

At Alice Holt, the plants used were 2+0 transplants moderately infected by *D. thujina*. At Sugar Hill the plants used were heavily infected 2+1 transplants imported from Dornoch Nursery (North Scotland). In both nurseries the experiments were of four blocks with randomised plots of two square-yards.

The sprays of 'Actidione BR' were prepared with 5% white oil emulsion, and those of 'Actispray' and semicarbazone 1% wettable powder by dilution with water.

Concentrations of materials applied (ppm):—

	Alice Holt	*Sugar Hill*
'Actidione BR'	10	5
	50	25
	150	75
'Actispray'	10	5
	42	10
	85	20
Semicarbazone	10	5
	50	25
	100	75

Three separate sets of control plots were used in each experiment.

In both nurseries the sprays were applied in the last week of March 1962, at the rate of 5 gallons/100 sq. yds., i.e., 450 ml./plot. Lesion counts at Alice Holt and Sugar Hill were made on 15th and 18th June respectively. Ten plants were collected from each treatment plot by regular sampling along the transplant lines. Two branchlets were taken from each plant, one at two inches and one at four inches from the top of the plant. Leaves showing active infection by *D. thujina* were counted by viewing the adaxial surface of each branchlet (if there was any doubt as to the adaxial surface, the side showing most lesions was examined). The results of the experiments are given in Table 23.

In both experiments 'Actidione BR' produced the greatest reduction in lesions counted. At Wareham, 'Actidione BR' at 25 ppm. produced the greatest reduction in lesion count, and this was significantly better than the effect at 5 ppm. However, there was no further reduction in the lesion count at 75 ppm. At Alice Holt there was no reduction in the lesion count at 150 ppm. compared with 50 ppm.

At both sites the number of lesions counted decreased almost linearly with increasing concentrations of 'Actispray' and semicarbazone. The lowest concentrations of both materials at Alice Holt, and the lowest concentration of semicarbazone at Sugar Hill, were not significantly better than the controls

Table 23

EFFECT OF CONCENTRATION, 1962. RESULTS

Treatment	Alice Holt		Sugar Hill	
	Conc. ppm.	Mean No. lesions per plot	Conc. ppm.	Mean No. lesions per plot
Actidione BR	10	13	5	79
	50	5	25	20
	150	6	75	22
Actispray	10	238	5	338
	42	68	10	179
	85	17	20	46
Semicarbazone	10	220	5	629
	50	79	25	498
	100	17	75	152
Control	(1)	340	(1)	856
	(2)	376	(2)	925
	(3)	302	(3)	885

although all produced a substantial reduction in the number of lesions counted. The highest concentrations of both materials at both sites produced very significant reduction in lesion counts compared with the untreated controls.

Although 'Actidione BR' was the most effective in the control of infection, it was the only material that produced symptoms of phytotoxicity at the concentrations used. All 'Actidione BR' plots showed symptoms of needle-browning, and some swelling and slight distortion of the apical shoots; the incidence of both types of damage increasing with increased concentration of material applied.

(ii) Effect of Time of Application

Two further experiments were carried out in Alice Holt and Sugar Hill nurseries in 1962, on ground immediately adjacent to that occupied by the 'concentration' experiments described above. Both experiments were of four block randomised plot layout, with treatment plots of two square yards. The object of these experiments was to examine the effect of delay in spray application. At each nursery only single concentrations of 'Actispray' and semicarbazone 1% wettable powder were applied, as follows:— Alice Holt: 'Actispray' 20 ppm., semicarbazone 50 ppm.; Sugar Hill: 'Actispray' 10 ppm., semicarbazone 25 ppm. All materials were applied at 5 galls./100 sq. yards. The times of application were:—last week in March only, last week in April only, and on both these occasions.

Infection assessment was made in mid-June at both nurseries, and the method of lesion counting was similar to that described above. The results appear in Table 24.

At Sugar Hill, application of 'Actispray' at 10 ppm in late March, and in both late March and April, gave similarly good control. Application in late April alone was not so effective; the difference was significant at the 5% level. Semicarbazone at 25 ppm. applied at both dates gave the greatest reduction in lesion counts. This reduction was significantly greater (at the 5% level)

Table 24

TIME OF APPLICATION, 1962. RESULTS

	Actispray 20 ppm.		Semicarbazone 50 ppm.	
	Time of Application	Mean lesion count per plot	Time of Application	Mean lesion count per plot
Alice Holt	Late March	136	Late March	99
	Late April	59	Late April	81
	Both dates	42	Both dates	24
	Mean lesion count in control plots—218			
	Actispray 10 ppm.		Semicarbazone 25 ppm.	
Sugar Hill	Late March	32	Late March	125
	Late April	131	Late April	228
	Both dates	30	Both dates	24
	Mean lesion count in control plots—666			

than that following application in late March alone, but the late March treatment was significantly better (at the 5% level) than late April treatment only. These results probably indicate that ascospore germination occurred soon after the late March treatment. At a later stage in disease development in late April, the applications at this time were less effective, although late April treatment alone produced a significant reduction in lesion count compared with "no treatment".

At Alice Holt, a different picture emerged. Treatment with 'Actispray' at 20 ppm. in late April alone, and at both dates, gave significantly better results (at the 5% level) than late March treatment alone. Late March treatment alone produced a substantial but not significant reduction in lesions compared with the untreated controls. With semicarbazone at 50 ppm., application at both dates gave significantly better control than late March treatment alone (at the 1% level), and than late April treatment alone (at the 5% level). Again, treatment in late March alone produced a considerable, but not significant, reduction in lesion count compared with the untreated controls. These results suggest that at Alice Holt germination of ascospores on the foliage surface was considerably delayed compared with that at Sugar Hill, so that the protective effect of the later application was enhanced.

The Effect of Mid-Season Application of 'Actispray'

In the six sets of untreated control plots in the 'concentration' and 'time of application' experiments at Sugar Hill, a further experiment was started in the summer of 1962 to compare the effect of mid-season applications of various concentrations of 'Actispray' on the development of infection in the following spring. 'Actispray' was applied at 20, 42, 85, 170 and 340 ppm., each at the rate of 5 gals./100 sq. yds., each treatment being replicated four times. Sprays were applied on August 13 1962. The plants were lifted in November 1962 and transplanted into a four block randomised plot layout in the Bourne Nursery, Alice Holt Forest. A preliminary assessment of general plant condition was made on May 27 1963. In all four blocks the plants appeared increasingly debilitated with decreasing concentration of 'Actispray', and appeared most unhealthy in the untreated control plots. However, the results from a detailed count of active lesions (by the method already described) showed that there was little difference in the lesion counts in the plots treated with 'Actispray' at and above 42 ppm., although there was a general slight decrease of lesions in these plots compared with those treated with 'Actispray' at only 20 ppm., and with the untreated controls. These results were not analysed statistically. The evidence of the general condition of the plants in May 1963 suggests that the treatment in August exerted some control effect on infection at that time, which was directly related to the concentration of 'Actispray' applied, but that the treatments had very little effect on the development of infection in the following spring. Spring infection probably originated from ascospores deposited on foliage while the plants were still at Sugar Hill, for a considerable period after spray application.

Comparison of Cycloheximide, Zineb and Maneb in the Control of Infection by Didymascella thujina

At the beginning of 1963, moderate infection by *D. thujina* on 2+1 *Thuja* transplants was reported in Tilhill Nursery, Tilford, Surrey. By the kindness of Messrs. Tilhill Forestry & Advisory Co. Ltd., permission was obtained to carry out a spraying experiment in this nursery. The experiment was designed to compare the effectiveness of 'Actispray' treatment with applications of zineb and maneb. The experiment consisted of four blocks of randomised plots, each two square yards in size. Treatments were:—'Actispray', at 42 and 85 ppm., Dithane Z-78 (60% zineb) at 1½ lbs. and 3 lbs./100 gallons water, and 'Dithane M-22' (80% maneb) at 3 lbs./100 gallons water. All materials were applied at 5 gals./100 sq. yds. on March 27 1963.

Lesion counting was made on June 11, using a regular sampling procedure similar to that described in previous experiments.

Results

Material applied	*Mean lesion count per plot*
'Actispray' 42 ppm.	24
„ 85 ppm.	6
'Dithane Z-78', 1½ lb./100 gals.	455
„ „ 3 „ „ „	749
'Dithane M-22' 3 „ „ „	579
No treatment (control)	592

None of the treatments with zineb and maneb caused a significant reduction in the lesion count compared with the untreated controls, whereas both concentrations of 'Actispray' produced a significant decrease (at the 5% level) in the number of lesions counted.

Additional Phytotoxicity Trials

In July 1962, a replicated phytotoxicity trial was started in uninfected 1+1 *Thuja* transplant stock at Roudham Nursery (East England). The materials tested were:—'Actidione BR' (in 5% white-oil emulsion), 5% white-oil emulsion, 'Actispray' at 10, 42, 85, 170 and 380 ppm., and semicarbazone 1% wettable powder at 10, 50, 100 and 200 ppm. All materials were applied at 200 ml./sq. yd. Visual assessment was made one month after the time of application.

'Actidione BR'. In the 5 ppm. plots, the foliage of transplants had a slightly dull appearance compared with the untreated controls, with chlorotic areas present at the base of most leaflets. At 25 ppm., the basal chlorosis was more pronounced, with general shoot-tip browning also present. At this time no distortion or stem thickening was recorded.

5% white-oil emulsion. No evidence of phytotoxicity was observed.

'Actispray'. Plots treated at 10, 42 and 85 ppm. were no different in appearance from untreated control plots. At 170 ppm. the foliage appeared dull and basal chlorosis of the leaflets was generally present. At 380 ppm., the degree and type of damage was very similar to that in plots treated with 'Actidione BR' at 25 ppm.

Semicarbazone. Only at 200 ppm. were phytotoxic symptoms observed, the type and degree of damage being similar to that in plots treated with 'Actispray' at 170 ppm.

A further visual assessment three months after application showed that there was little general change in the symptoms. Marked reduction in height growth was evident in plots treated with 'Actidione BR' at 25 ppm. and 'Actispray' at 380 ppm. In plots where basal chlorosis of leaflets was recorded previously, this was now less marked. In 'Actidione' plots, at both concentrations, and in the plots receiving the highest concentrations of 'Actispray' and semicarbazone, reddening of the stem scale leaflets had occurred.

In an adjacent area in the same nursery, fortnightly treatments in a triplicated plot layout were carried out, commencing in July, to test the effect of repeated application of 'Actispray' at 42 and 85 ppm. One set of three one-yard-square plots received one, two and three applications of 'Actispray' at both rates. At the time of visual assessment three months after initial application, there was very little difference in plots so treated compared with the untreated controls, although irregular but slight basal chlorosis of young leaflets was observed in plots which had received more than one treatment.

Summary of Spray Trials

The results of the experiments described indicated that if applied at or just before the time of ascospore germination in the spring, all concentrations of the cycloheximide materials tested decreased the level of subsequent infection. With all materials (except 'Actidione BR'), at the concentrations used, increase in concentration caused more effective control of infection. With 'Actidione BR', increase in concentration above 50 ppm. produced no significant increase in the level of control.

There was evidence that cycloheximide fungicides, applied in summer and autumn, reduced infection in that growing season, but had little or no effect on the development of infection in the following spring. This suggests that the activity of these fungicides is largely, or entirely protective, with very little, if any, systemic effect. Zineb and maneb appeared ineffective in controlling infection caused by *D. thujina.*

Materials for Larger Scale Use in Forest Nurseries

In selecting the best material for regular use in forest nurseries against *Didymascella thujina*, phytotoxic effects and market availability of the materials are very important, as well as fungicidal activity. 'Actidione BR', although producing the most effective control of the disease was much more phytotoxic than any of the other materials tested. Apart from this, the procedure of mixing with white-oil emulsion was laborious and generally unsuitable for large-scale use. The oxime and acetate derivatives used in the experiments were crystalline experimental materials, and as far as is known, these substances are not available in a commercial form suitable for large scale use. Wettable powder formulations of semicarbazone are easy to mix, but although used on a fairly extensive scale experimentally this material is not available in a proprietary form. 'Acti-spray' is marketed in the United States, particularly for use against shot-hole disease of cherries, caused by *Higginsia hiemalis*, and is also recommended there for use against a number of other diseases. The material is supplied in a convenient lozenge form, and although care must be taken in the initial dispersion of the lozenge, preparation of the spray presents little practical difficulty.

At the time of writing, 'Actispray', which is manufactured by Upjohn Co. of Kalamazoo, U.S.A., is only available in Britain for use in experimental work supervised by research personnel. Its wider use here is subject to commercial considerations and the regulations imposed by the Notification of Pesticides Scheme of the Ministry of Agriculture, Fisheries and Food. The cost of the material is high, and at the price at which 'Actispray' is available in Britain at present, the cost of application at 75 ppm. at 200 gallons per acre is about £48 per acre of *Thuja* nursery stock. However, considering the value of the stock, the serious nature of infection by *Didymascella*, and the effectiveness of disease control achieved, the use of this material would appear to be a sound economic proposition, if applied at the correct time.

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APPARENT VARIATIONS IN THE RESISTANCE OF POPLAR CLONES TO BACTERIAL CANKER

By J. JOBLING and C. W. T. YOUNG

Introduction

Since poplars are grown mainly for veneer timber, and are generally planted at such wide spacing that there is little or no scope for sanitation thinning without loss of revenue, resistance to bacterial canker must be a major consideration in deciding which clones should be recommended for planting. This article describes past work on the testing of clones for resistance, some anomalies between the results of this work and the behaviour of the disease under natural conditions of infection, and current work arising from these anomalies.

The nomenclature in the text follows the rules of the International Code of Nomenclature for Cultivated Plants. Letters or numbers following the name of the species or hybrid usually relate to the origin of the particular clone and are for record purposes only.

Causal Agent

Although the disease was first recorded in the late 19th century, and was subsequently investigated by many workers, the causal agent remained undiscovered until recent years, when Ridé (1958) isolated a previously unknown bacterium, *Aplanobacterium populi* Ridé, that could reproduce the disease on inoculation with pure cultures. Previous workers had attributed the disease to various bacteria, none of which produced typical symptoms when inoculations were made using pure cultures. At the time of Ridé's discovery, *Pseudomonas syringae* sub-species *populea* Sabet was generally thought to be the main pathogen. Ridé's findings have been confirmed by de Lange and Kerling (1962) and by Whitbread (unpublished thesis).

Testing of Clones for Resistance

In 1952 a series of annual inoculation tests of clones was started, and this continued until 1962 (Peace unpublished). Inoculations with natural bacterial slime were made in May each year on some 200 or more clones, planted at close spacing under nursery conditions mainly as one-year unrooted sets, generally 10 per clone. The first assessments for canker development were made in the August of the following year, some 15 months after inoculation, and annual assessments were made in August thereafter.

Some clones were consistently resistant in the tests, while others were consistently susceptible, and between these extremes was a considerable number that gave results varying, sometimes widely, from year to year. Depending mainly on the results of these inoculations, provisional resistance ratings were given to the clones when sufficient data were considered available. Five ratings were employed: (1) 'very resistant', (2) 'moderately resistant', (3) 'middle group', (4) 'moderately susceptible', and (5) 'very susceptible'. Clones in the first two groups were considered suitable for general use, provided they were silviculturally desirable.

By 1963 it had become evident from field observations that the tests could provide definitive proofs of susceptibility only, not of resistance, and that research on a broader basis was required.

Apparent Breakdown in Resistance in the Field

In 1961 a survey of natural canker was made in the Research Branch's poplar varietal plot areas, which are widely distributed throughout Britain. Bacterial canker had been brought into these areas several years earlier by inoculation of scattered susceptible trees to provide sources of natural infection.

Considerable variations between areas in the incidence of natural canker were found. In the more severely affected areas canker was present not only on susceptible clones, but also on several 'very resistant' ones that, by definition, had not shown markedly variable resistance in the tests. In the least-affected areas little or no canker was found, even on very susceptible clones. These variations were in no way related to geographic location, age of crop, or to any obvious differences between site characteristics, such as fertility, soil type, moistness, liability to frost, and so on.

In 1962 fairly severe outbreaks of natural canker were found on the 'very resistant' clones *Populus trichocarpa* CF, *P. tacamahaca* × *trichocarpa* 32 and *P. tacamahaca* × *trichocarpa* 37, inoculated in the 1959 and 1960 annual tests at Fen Row Nursery, Aldewood Forest, Suffolk, and this extensive damage on plants that were then canker-free at the points of inoculation was striking negation of the evidence of resistance previously found in the tests.

Whitbread (unpublished thesis) has suggested that natural bacterial slime may not be a reliable inoculum, and that this would account for the apparent resistance of inoculated clones that were in fact susceptible. In the annual tests, however, very susceptible clones were consistently infected on inoculation; e.g., out of 153 inoculations on susceptible *P. generosa*, only eight did not take, a result which does not suggest that the inoculum was particularly unreliable.

Possibility of Various Bacterial Strains

A possible explanation of the discrepancies between inoculation results and natural infection is that there are local strains of the bacterium varying in pathogenicity. The standard slime used in all the inoculation tests was obtained from cankered poplars at Ling Heath, Brandon, Suffolk, while the natural infection of 'very resistant' clones in the tests at Fen Row could have come from cankered poplar plantations adjoining the test area. To explore this possibility an experiment was started in 1963 in which a number of clones, planted as one-year unrooted sets, were inoculated with slime from three areas: (1) Ling Heath, (2) Fen Row, and (3) Creran Forest, Argyll, a poplar varietal plot area in which canker was particularly virulent. The inoculations were done in May, and the first assessments were made about three months later. Since there was some urgency to get information about silviculturally valuable clones, as many of these as were available were put into the experiment, which was consequently rather large. Application of treatments was a fairly lengthy business, and, unfortunately, the weather at the time was extremely variable, heavy showers alternating with brilliant sunshine. The results of the first assessment, summarised in Table 25, are from two of the three replications in the experiment. In the third replication, infection by the standard Ling Heath slime was so much less than in the other two replications that it looked as though the inoculum might have been excessively diluted or washed out by heavy rain. Many of the one-year sets were of poor quality—a result of the cold, dry 1962 growing season and the following severe winter—and six clones have been excluded because of poor survival.

Table 25

RESISTANCE TO BACTERIAL CANKER FROM DIFFERENT SOURCES, AND RESISTANCE DERIVED FROM ANNUAL TESTS

Clone	Score for susceptibility			
	Source of bacterial slime			1952–1962 Annual Tests
	Ling Heath	Creran	Fen Row	
berolinensis B	1	1	1	1
berolinensis R	1	1	1	1
gelrica HA	1	1	1	1
gelrica VB	1	1	1	1
trichocarpa MB	1	2	2	1
eugenei PU	1	2	2	2
tacamahaca x trichocarpa 37	2	2	3	1
serotina VB	2	3	2	1
eugenei UL	2	2–3	2–3	2
tacamahaca x trichocarpa 32	2	4	4–5	1
trichocarpa CF	2–3	4–5	5	1
generosa OP 250	5	4	4–5	4

1 = Very resistant. 2 = Moderately resistant. 3 = Middle group.
4 = Moderately susceptible. 5 = Very susceptible.

Four clones, two of *P.* 'berolinensis' and two of *P.* 'gelrica', appeared very resistant, and *P.* 'generosa' was moderately or very susceptible, to all three slimes. Five clones appeared slightly more susceptible to one or both of the non-standard Creran and Fen Row slimes than to the standard Ling Heath slime, and two clones, *P. tacamahaca* × *trichocarpa* 32 and *P. trichocarpa* CF, were strikingly more susceptible to both the non-standard slimes. While these results appear to support the theory that there are strains of the bacterium varying in pathogenicity, they are not conclusive, particularly in view of the unsatisfactory conditions under which treatments were applied. To test the validity of the results, a simplified experiment has been designed, in which Ling Heath and Fen Row slimes will be compared on *P. tacamahaca* × *trichocarpa* 32.

The Meaning of 'Resistance'

There are apparent discrepancies in Table 25 between the resistance ratings derived from the 1952–1962 annual tests and the ratings in the 1963 experiment as regards the standard Ling Heath slime, always used in the annual tests. These differences are probably between resistance to initial infection (assessed three months after inoculation in the experiment) and resistance to continuing canker development after infection. In the annual tests, assessments were first made 15 months after inoculation, by which time nearly two growing seasons had elapsed, and some recovery from initial infection could have taken place. Furthermore, a clone was rated as resistant if it recovered well from observed infection. Thus *P.* 'serotina' VB, *P. tacamahaca* × *trichocarpa* 32 and 37, all 'moderately resistant' in the experiment, had been classed as 'very resistant' in the annual tests despite 30–50% inoculation takes, because they recovered within two or three years. *P. trichocarpa* CF, however, had never shown definite indications of susceptibility in the annual tests, only one, very slight, temporary infection having been recorded after 56 inoculations. Yet in the experiment its rating for resistance to initial infection by the standard slime was marginal between 'moderately resistant' and 'middle group'. This suggests that in the annual tests *P. trichocarpa* CF recovered so rapidly, despite appreciable infection, that virtually no canker remained by the time the first assessment was made.

Initial Differences in Extent Between Inoculation and Natural Infection

Some distinction must be made between a clone's resistance to initial infection and its ability to seal off and recover from infection. Inoculation involves a small wound, made by a downward cut 1–1·5 cm. long in the bark and slightly into the wood, and, while a clone may recover from so limited an infection without suffering economically appreciable damage, the situation may be considerably changed where initial infection is more extensive.

Little work has been done on natural infection. It is not known how the disease spreads from tree to tree, but there is some evidence on how it gains entry and on the extent of initial infection.

Infection of Leaf Scars

Ridé (1959) found that fresh leaf-scars in autumn could be infected by the application of *Aplanobacterium populi* in pure culture, and we have observed natural canker formation round leaf gaps on the branches of susceptible *P. trichocarpa*. The annual inoculation tests, however, should adequately indicate the risks of canker development from such small initial infections.

Infection of Winter Cold Injury

In Germany, Joachim (1962) investigated various forms of stem injury, including bacterial canker, and found that they were all mainly associated with dormant periods in which mild spells were followed by cold in February or March. Most of the bacterial cankers were at branch bases, zones that are particularly sensitive to frost, and he considered that low temperature injury was an important factor in bacterial canker infection. Canker specifically associated with branch bases has been observed in Britain on known susceptible clones, but it was not a feature in the cankering of 'very resistant' clones.

Infection of Tunnels Made by Cambium Boring Larvae of Agromyzid Flies

In August 1963, a close examination was made of cankered stems of 'moderately resistant' *P.* 'robusta' MD in the inoculation test area at Fen Row. The trees were inoculated in 1956 and had recovered from infection by 1959. After that no canker was observed until 1962, when a fairly severe outbreak of stem canker was recorded. The cankers were of a characteristically elongated form (Plate 12, a), and examination revealed that they were associated with tunnels made by cambium boring larvae of flies in the family *Agromyzidae.* Cankered stems of the 'very resistant' clones *P. trichocarpa* CF, *P. tacamahaca* × *trichocarpa* 32 and 37, were then examined and all the cankers were found to be associated with agromyzid tunnels (Plate 12). Subsequent examination of material from various parts of Britain indicated that this type of canker was of widespread occurrence, and that agromyzid damage, previously considered to be of relatively minor importance, could lead to major economic loss through stem canker. It was, however, known that agromyzid tunnels in willows could provide entry for bacterial rot (Barnes 1933).

Observational evidence so far suggests that the insect does not act as a vector, and that infection takes place through the exit holes. Tunnels associated with canker are invariably stained (Plate 12, c), the colour varying from pale yellow to deep brown, and are situated in wood formed during the latter half of the growing season, often towards the end. Tunnels go up the stem to exit holes, traces of which remain clearly visible in the bark epidermis for at least a year. Staining extends from exit holes for considerably varying distances down the tunnels, and the presence of stained tunnels can often be detected externally by slight or fairly pronounced swellings on the stem over their courses. Sometimes the uppermost canker associated with a tunnel has its apex at the exit hole, but not invariably so. Cankerous lesions involving death of cambium over parts of a tunnel develop on the end of the ring in which the tunnel is situated, and usually a wall of late summerwood separates the tunnel and its accompanying cankers. This separating wall may occasionally be absent where tunnels are made at or very close to the end of the growing season, and in these instances very long lesions over the tunnels may form and then be occluded over much of their lengths with open canker development only at intervals (Plate 12, d).

While further work is needed before definite conclusions can be drawn, it looks as though the bacterium enters through the insect's exit holes, colonizes and spreads rapidly down the parenchyma cells with which the tunnels are filled, and then infects the outer tissues, usually at intervals, over the infected tunnels' lengths. This type of canker is particularly important since it affects the stems. Even though a clone has powers of rapid recovery, intermittent attacks would greatly reduce its value as veneer timber (Plate 12, b). Work on the bacterial canker—agromyzid association will include field surveys of its incidence, experimentation to determine the role played by the insect, and a study of the agromyzid involved. In France, Ridé (personal communication) has observed a similar association, and on a recent visit to this country he confirmed the importance of the problem.

Variations Between Sites in the Incidence of Bacterial Canker

The possibility that there are local strains of the bacterium varying in pathogenicity would not explain observed variations between the poplar varietal plot areas in bacterial canker behaviour. If there are different strains, then that at Fen Row is certainly one of the more virulent. Fen Row Nursery, however, was the main source of planting stock for the varietal plot areas, and naturally infected plants probably went to all areas, and are known to have gone to some areas where there has been little or no spread of canker. In 1955, susceptible *P. trichocarpa* GD was planted in the varietal plots at Dyfnant Forest, Montgomery, to provide sources of natural infection after inoculation the following year. Several of these plants had already become naturally infected in Fen Row Nursery. In 1961, out of 176 trees of clones that showed some degree of susceptibility elsewhere, only two had canker at Dyfnant. The inoculated and naturally infected *P. trichocarpa* GD trees were still cankered, but there had been no spread of canker to post-1956 growth on these trees, which had increased in height by some 25 ft. or more. In the varietal plots at Quantock Forest, Somerset, there has been negligible spread of canker, despite the presence of many susceptible clones, including *P. generosa* naturally infected at Fen Row before planting in 1955. In contrast to these two examples, much younger plots at Creran have become the most severely cankered of all; yet experimental results (Table 25) did not indicate any marked difference in pathogenicity between Creran canker and Fen Row canker, which had been introduced into the relatively canker-free Dyfnant and Quantock plots.

Whether variations in the incidence of agromyzid attack between the plot areas is related to canker incidence variations is not known; it will be investigated as far as silvicultural considerations allow. Veneer tests of timber from a few trees in the relatively canker-free Quantock area have shown that the insects are certainly present there, but more extensive sampling is needed to gauge the frequency and severity of attacks.

While the variations between sites in canker incidence may be due to chance differences in variable factors favouring infection, there remains the intriguing possibility that obscure permanent site factors are involved, and two experiments have been designed to explore this possibility. The importance of this aspect of the problem is best exemplified by the performance of *P.* 'Androscoggin' in the varietal plots. *P.* 'Androscoggin' is one of several very fast growing *P. maximowiczii* × *trichocarpa* clones that are not recommended for planting because of their susceptibility to canker. In the Creran plots six-year-old *P.* 'Androscoggin' is riddled with canker and is dying back; in the Quantock plots it is canker-free and is the fastest growing tree in Britain, with an average height of 86·5 ft. at 14 years, and an average girth at breast height of 40·5 ins. If this tree could be grown on a large scale without risk of canker, poplar timber production would be revolutionised.

Summary

Some poplar clones rated as very resistant to bacterial canker (*Aplanobacterium populi,* Ridé) in inoculation tests have proved susceptible to natural infection in the field. Inconclusive experimental results suggested that strains of the bacterium varying in pathogenicity might be involved in this apparent breakdown in resistance. The tunnels of cambium boring larvae (family *Agromyzidae*) provide the bacterium with a means of entry and spread, giving

rise to much more extensive initial infection than is achieved by inoculation, and clones classified as resistant because of their ability to recover from infection on inoculation are liable to extensive damage in this way. Variations between sites in the incidence of bacterial canker are being investigated.

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SOME EARLY RESPONSES TO INCREASED INTENSITY OF HEATHLAND CULTIVATION

By D. W. HENMAN

The very great benefits provided by ploughing in the afforestation of upland heaths are universally recognised. They were fully described by Zehetmayr (1960) by which time the practice of single-furrow ploughing at about 5 ft. spacing had become fairly standardised, using the Tine plough on Scottish heaths and the R.L.R. plough (and more recently the Tine) in north-east England. On the most intractable sites such ploughing has made the difference between virtual failure and an acceptable crop; on better sites improvements in growth may amount to a Quality Class or more; even on loose, free-draining and fertile soils, where the actual working of the soil confers little benefit, the suppression of vegetation by ploughing may reduce weeding costs or the period spent in the establishment stage sufficiently to show calculable financial benefits. Zehetmayr (1960, pages 60–62) described spaced-furrow ploughing as 'the minimum required to give establishment within a reasonable period' and suggested that the cost of more intensive cultivation would be out of all proportion to the limited benefit to growth demonstrated in experiments to date. Nevertheless, it was natural to examine the effects of increasing the intensity of cultivation, and carefully designed experiments have been established with plots large enough to give volume production data over a whole rotation (or several rotations) from a range of intensities of soil working. The present paper describes the results, based on height growth, from the two oldest of these experiments after ten years' growth.

The Experiments

These are at Teindland Forest, Moray (*Expt.* 81 P.52) and Harwood Dale, Allerston Forest, Yorkshire (*Expt.* 41 P. 54). Both are sited on *Calluna* heath at fairly high elevation (700–800 ft.) and exposure. The cultivation treatments and species tested are very similar in each. Despite these similarities, the results vary considerably between the two experiments; this is thought to be due to differences between the soils, and is discussed later in the paper.

Cultivation Treatments

The two established methods of spaced-furrow ploughing—Tine and R.L.R.—are compared, together with three intensities of complete ploughing, namely: 'shallow', 'shallow with subsoiling' and 'deep'. The methods, and the effects achieved in terms of depth and volume of soil cultivated, are shown in Table 26, adapted from Zehetmayr (1960) Table 13, page 50. In addition, each experiment has an unreplicated 'control' plot, in which the three main species have been directly notch-planted. This provides a demonstration of the sites' capabilities without mechanical interference.

All plots received phosphate in the form of 1½ oz. ground mineral phosphate per plant at time of planting.

Table 26

METHODS OF PLOUGHING AND THE EFFECTS ACHIEVED

Method of ploughing	Depth of soil disturbance* (ins.)		Volume of disturbed soil per plant (cu. ft.)	
	Teindland	Harwood Dale	Teindland	Hardwood Dale
A Deep; single furrow at 4½ ft. spacing.	12·0	10·5	6·6	6·0
B Tine; single furrow at 4½ ft. spacing.	16·4	14·8	7·8	6·2‡
C Shallow; complete	6·7	6·2	10·8	8·2
D Shallow; complete, plus subsoiling at 9 ft. spacing.	7·4 16·8†	6·3 22·7†	15·2	7·5‡
E Deep; complete	12·9	13·4	24·7	23·0
F Deep; complete, plus rototilling of ploughed surface.	12·2	—	23·9	—

* The depth of soil disturbance usually exceeded by several inches the depth of penetration of the plough-share or tine point.

† Depth disturbed by sub-soiling tine, beneath depth of soil turnover achieved by the mouldboard.

‡ The full extent of soil disturbance due to the passage of the subsoiling tine was not detectable in the clayey soil at Harwood Dale.

Species

Two main crops are compared in each experiment, in plots large enough to give rotation-length results of volume production. In addition a number of small plots are included of higher-yielding species which, however, might prove too demanding for such poor or exposed sites. At both sites, pure Scots pine was used, as being the conventional main-crop choice for the areas; the second main-crop at Teindland was Lodgepole pine/Japanese larch in 3 row/3 row mixture; at Harwood Dale it was Corsican pine/Japanese larch in 3 row/3 row mixture; these crops were chosen as likely to be more productive than pure Scots pine. Subsidiary species (in small plots) were Sitka spruce, Norway spruce and hemlock at both forests, with Douglas fir at Teindland and Serbian spruce, *Abies grandis* and *Abies procera* at Harwood Dale; all these are mixed with Japanese larch to nurse them through the period of check by heather (*Calluna vulgaris*).

Experimental Design

This is the same at both forests. The main plots (cultivations) are each replicated three times in randomised blocks. Each one is split into two large sub-plots of 2/5 acre for the 'long-term' species, and a number of small ones of ⅓ to ½ square chain for the subsidiary species.

Assessments

The height of the crops has been measured at 3 years, 6 years and 10 years of age. On the first two occasions the *mean heights* were recorded, which represent the whole range of growth of individual plants. At the ten-year assessment the *dominant heights* were recorded, representing the tallest 240 trees per acre distributed evenly over the plots; these are the trees which are likely to remain in the crop for most of the rotation. Mean height of all the trees was recorded for the subsidiary species at each assessment.

Results

Heights at ten-years-old are shown in Table 27 for each site, species and cultivation method. They can conveniently be discussed under the same headings.

Sites

Growth of the directly-notched plants shows that the capacity of the uncultivated Harwood Dale site is greater than that of the Teindland site,—insofar as a comparison can be made between unreplicated plots and possibly, different provenances, (Scots pine at Harwood Dale is of 'Thetford' origin, that at Teindland is from Culbin; but neither 'Thetford' nor Culbin are natural forests, and the original provenance of the parent trees is unknown. Japanese larch at both sites is imported from Japan, but not further distinguishable). The differences in site performance can probably be attributed to lower nutrient status of the upper soil layers, tougher raw humus and greater surface wetness at Teindland, as evidenced by the high proportion of deer grass (*Trichophorum*) to heather there; before planting, deer grass was the dominant vegetation in parts of the Teindland site, whereas it appeared in only a few areas at Harwood Dale.

Table 27

HEIGHTS AT TEN YEARS OLD

PART A. LARGE PLOTS (DOMINANT HEIGHTS IN FEET)

Cultivation method:	Teindland			Harwood Dale		
	Pure	*Mixed*		*Pure*	*Mixed*	
	Scots pine	Lodgepole pine	Japanese larch	Scots pine	Corsican pine	Japanese larch
A Deep, spaced furrow	6·8	8·9	11·5	7·1	9·2	10·8
B Tine, spaced furrow	6·8	9·4	11·9	6·7	8·8	9·5
C Shallow, complete	7·9	11·5	13·6	6·7	8·5	8·6
D Shallow, comp., + tine at 9 ft.	8·3	10·6	13·1	6·6	8·1	7·5
E Deep, complete	8·8	12·4	15·3	7·9	10·0	11·9
F Deep, comp., + surface cult.	8·4	11·1	13·6	—	—	—
Standard error (±)	0·29**	0·42**	0·51**	0·45	0·43	0·89
Direct-notched control (Mean Ht.)	2·3	2·7	1·6	4·5	4·3	2·6

PART B. SMALL PLOTS (MEAN HEIGHTS IN FEET)

Cultivation method:	Teindland				Harwood Dale					
	Nursed by Japanese larch				*Nursed by Japanese larch*					
	Sitka spruce	Norway spruce	Hemlock	Douglas fir	Sitka spruce	Norway spruce	Picea omorica	Hemlock	Abies grandis	Abies procera
A. Deep, spaced furrow	1·4	1·2	3·3	3·8	6·1	4·2	3·9	2·9	3·6	3·2
B. Tine, spaced furrow	4·1	2·5	4·0	4·3	6·5	2·8	3·7	3·5	3·6	2·9
C. Shallow, complete	6·3	3·4	6·2	4·4	5·5	2·7	3·1	2·5	2·7	2·8
D. Shallow, complete + sub-soiling	4·9	2·7	5·7	4·4	5·2	2·3	3·3	2·5	2·1	2·6
E. Deep, complete	8·3	4·6	7·9	7·8	7·0	3·4	4·2	3·8	3·8	3·6
F. Deep, complete + roto-tilling	6·9	3·7	6·7	7·6	—	—	—	—	—	—
Standard error (±)	1·06*	0·70	0·87*	0·60**	Not calculated					

* = Differences between treatments are significant at the 5% level.

** = Differences between treatments are significant at the 1% level. (Differences not significant at Harwood Dale).

After ploughing, height growth has been slightly better at Teindland for any given species or treatment, so it can be said that the relative response to ploughing has been about twice as great there as at Harwood Dale.

There has also been a greater response *between* various ploughing treatments at Teindland, especially by the more demanding (subsidiary) species, and this, together with the consistency of the results between the three replications, has conferred a high level of statistical precision on the Teindland results. Statistical significance at the 5% level or better in the Harwood Dale results is lacking, owing mainly to the irregular behaviour of certain sub-plots; the soil contains many large boulders which made clear and consistent differences in depth and intensity of cultivation between treatments almost impossible to achieve.

Species

Of the three main species, Japanese larch has grown the least without ploughing and the most with it; that is, it is the most responsive to cultivation of some kind; at Harwood Dale it is also more responsive to the particular *kind* of ploughing, though not at Teindland. Scots pine is the least responsive. The more demanding species are considerably more sensitive to kind of ploughing than are the three main species, and this is particularly so at Teindland.

The results to date justify the choice of main species made for the two sites; i.e. that Scots pine is a 'safe' and healthy choice but that Japanese larch with Corsican or Lodgepole pine is likely to be more productive. The long-term performances of Corsican pine in the *Brunchorstia*-susceptible region of Harwood Dale, and of this particular provenance of Lodgepole pine (West Montana) at Teindland, remain in some doubt, however. Of the higher-yielding, but probably more demanding, species nursed by Japanese larch, Sitka spruce is the only one to show much promise at Harwood Dale, where it challenges Scots pine on all ploughing treatments. At Teindland, Sitka spruce, hemlock and Douglas fir are all well up with Scots pine, but only on the most intensive forms of cultivation.

Cultivation Methods

The size and order of the effects given by the different methods of cultivation are quite different at the two sites. At Teindland there is a distinction between the spaced-furrow ploughings on the one hand (Treatments A and B) and the complete ploughings on the other, the latter giving improved height growth. At Harwood Dale the distinctions are less clear-cut, but show a clear benefit from deep complete ploughing (E), rather less from deep single-furrow ploughing (A) and least from shallow ploughing, either single-furrow or complete, with or without sub-soiling. The effect of the sub-soiling tines in Treatments B and D, was thought to be very slight in this clay soil, as regards disturbing the soil through which they passed. Results from both sites show a correlation between height growth and volume of soil disturbed, though this is less evident at Harwood Dale where only the extremes of soil disturbance are represented. (See Table 26).

The difference between the sites may be interpreted on the following lines. The main early need at Teindland is for aerobic conditions in the upper soil layers, sealed by the thin (3 ins.) tough peat skin, but otherwise fairly porous; then freedom from heather (*Calluna*), which competes for the rather low nutrient (especially nitrogen) supply. Height growth is quite closely correlated negatively with percentage heather cover on each ploughing treatment, and this is the only possible explanation of the consistently poorer growth on the deep complete ploughing which was subsequently rotovated (Treatment F); re-growth of heather has been denser and more rapid there than in any other treatment. At Harwood Dale the need is for more general aeration of the soil, which is a rather heavy clay-loam and thus inherently less permeable; also it has a rather deeper peat layer (5 ins.). The improved aeration is provided by the deep, digging and turning action of Treatments A and E rather than by the inversion of the upper peat layer only, as in Treatments B-D. Here also, there is a negative correlation between height growth and percentage heather cover.

A feature of the early development of some conifer species on ploughed heath soils is a tendency for trees to become loosened and blown sideways when about 4 to 6 ft. tall. Trees damaged in this way rarely contribute usable produce and can almost be rated with dead plants when assessing crop survival percentages. The damage is particularly evident with species of pine, and where planting has been on the sides or bottom of the furrow of spaced-furrow ploughing. It is much less evident, even in susceptible species, where planting has been on the ridge of spaced-furrow ploughing or on complete ploughing. The problem has been considered in detail by Edwards, Atterson and Howell (1963) who use data from the two experiments described here. These show very highly significant differences in the percentages of loosened Scots pine, Lodgepole pine, and Japanese larch at Teindland, and of Corsican pine at Harwood Dale, between the two spaced-furrow ploughing treatments on the one hand and the complete ploughing on the other. In the worst cases, 'losses' of over 25% were involved. Planting at both sites was in the furrow.

If these results are considered in relation to current ploughing practice on mineral heaths, it is seen that at Harwood Dale deep complete ploughing is the only alternative which offers any improvement over local practice, whereas at Teindland any kind of complete ploughing has improved growth, with "deep complete" giving the greatest improvement. The greatest benefits, in terms of height growth of the main species, are of the order of 10% at Harwood Dale and 30% at Teindland after only ten years' growth; or, in more practical terms, the greatest improvement at Harwood Dale represents one year's height growth and at Teindland, three years. In the subsidiary species at Teindland, improvements of 80–100% have resulted.

Discussion

How long these relative improvements will be maintained is difficult to forecast; to expect a 30% increase in final volume yield is clearly too optimistic. But as this is an important question to the practitioner faced with ploughing programmes, some reasoned speculation is justified. The improved early growth is almost certainly partly due to greater freedom from heather competition, and perhaps to the release of nutrients from mechanically suppressed vegetation; hence differences due only to these causes may be expected to diminish when suppression by canopy closure takes place in the less intensively ploughed treatments. It is noteworthy, however, that the heights at ten years old do not merely reflect improvements attained at six years of age; height increments during the interval show that the best treatments were still improving. At this stage the effects due to vegetation would be decreasing in importance, and it is reasonable to suppose that the cultivation of the soil itself was showing real benefit. This effect can be expected to increase as the crops make increasing demands on the rootable soil volume for moisture and nutrients. However, the soil at Harwood Dale, while of a clayey texture, is stony and not compacted, and it is probable that the benefits of deep complete ploughing will never be as great there as at Teindland, where the severely indurated sandy drift appears to be almost impenetrable by tree roots below about nine inches. The compactness of the Teindland soil is demonstrated by the rooting characteristics of Lodgepole pine in a neighbouring experiment, planted in 1929 on shallow (7 ins.) complete-ploughed bands, where the roots of trees exposed by windthrow have become rough, worn stubs where they bear on the pavement-like compacted layer just below the depth of the cultivation.

In contrast to some heath soils which have a relatively thin impeding iron pan within an otherwise freely-draining, aerated and rootable soil, the compaction of the drift at Teindland and other parts of North-east Scotland usually extends downwards for several feet. In soils of the former type the tine plough can provide great benefits by breaking the pan and allowing downward water percolation and root access to open soil; in the latter type, as at Teindland, the cultivation effect due to the passage of the tine appears to be rather slight, and little use is made of the tine channel by tree roots, at least up to the thicket stage. The success of this plough on such sites lies mainly in its being a robust and trouble-free implement for producing a vegetation-free strip with loosened soil for planting in (either in the furrow or on the ridge) whereby the initial establishment of plantations on mineral soils can be almost assured. For making a greater volume of soil available for rooting during the pole stage and later, experience at Teindland and on the Black Isle (Ross and Cromarty) suggests that some form of deep complete cultivation is both necessary and rewarding, and, moreover, that the depths and cultivated volumes achieved in experiments to date do not represent the limits from which a growth response may be obtained. There is a strong case, therefore, for testing still deeper complete cultivation, even if special machinery has to be developed, bearing in mind that the effects will benefit successive rotations of crops. Ground which has once borne a mature crop will be difficult to re-cultivate, and in anticipation that such deeper cultivation will provide significant production and financial benefits, the ability to achieve the same effect in stump-covered ground by the use of explosives (placed to produce a confined sub-surface shock-wave) may be investigated.

The present results give less justification for the general adoption of complete deep ploughing on sites such as Harwood Dale. However, these clayey soils with a heath vegetation, which are typical of many forests in the North-east of England, are being increasingly recognised as presenting winter drainage problems. Deep drains (say 30–36 ins.) are required to lower the perched water-tables, and the movement of water into these drains will be accelerated by any improvement to the structure of the soil down to this depth. In the Harwood Dale experiment even the deepest ploughing did not penetrate far into the poorly-structured sub-soil, but it is probable that much deeper complete cultivation, in conjunction with a system of deep drains, could greatly reduce winter water-logging and show considerable improvements in growth relative to spaced-furrow ploughing.

There is now hope that machinery capable of achieving an overall soil disturbance down to depths of 24 ins. may be available for experimental work quite soon. Experiments will be established both on the compacted tills of North-east Scotland and on the clayey soils of North-east and North England.

Where it is proposed to plant Corsican or Lodgepole pines on heath sites on which wind-loosening is anticipated, and if a planting position on the ridge is for any reason unacceptable, the reduction in wind-loosening 'losses' which results from complete ploughing is added to the benefits of faster growth. If, furthermore, this enhanced stability is carried over into the pole stage the managerial and financial advantages are obtained of a rotation length which is not controlled by wind-throw. Up to the present, crops on the hard heathland sites are not of sufficient height to show whether wind-throw will be an important factor in their management.

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WINDTHROW ON THE MARGINS OF VARIOUS SIZES OF FELLING AREA

By S. A. NEUSTEIN

Introduction

Unlike many parts of the country where a natural irregularity of crop, soil and vegetation has led to stands of limited extent, much of the Border area consists characteristically of large, pure, even-aged spruce plantations. Smooth rolling hills provide little geomorphic shelter and the prevailing soils are such that deep root development is uncommon. Crop irregularity of a degree which might be considered of value in siting felling areas consists either of small local variations of tree height equivalent perhaps to one Quality Class, or else, less frequently, of greater height differences due to parts of a Compartment having suffered a period of checked growth. Nevertheless it remains generally true that at the regeneration stage there will be few naturally stable features of site or crop which a forester can hope to rely on to restrict the extension by windthrow of clear felled areas.

In 1961/62 an experiment was established in the Forest of Ae, Dumfriesshire, with the primary object of comparing the windthrow resulting from felling areas of various sizes. The progress of this experiment has been briefly referred to in the annual *Research Reports* of 1961, 1962 and 1963.

Objects of the Experiment

The main object of the experiment is to compare, in a regular, shallow-rooted Quality IV/V Sitka spruce crop (planted 1927–31), the stability of the margins of four sizes of circular felling area, viz. 0·1 acre (10 plots), 0·3 (3 plots), 1 acre (3 plots) and 10 acres (1 plot). It has been contended by some foresters that small clearings reduce the incidence of consequent windthrow by reducing the 'sweep' of wind within them. Opponents of small clearings have pointed to the arithmetical fact that the length of susceptible margin per acre felled rises rapidly as the felling area diminishes, and also to the management difficulties of small scattered crops.

The secondary object of the experiment is to compare the survival and early growth of two species, Norway and Sitka spruce, when planted at different times in relation to the felling date. Subsidiary plans were made to investigate the effect of clearing size on the rate of re-invasion of vegetation and consequent weeding requirements. In addition the feasibility of lop and top disposal by means of Wilder Rainthorpe Chopper was investigated, and minor trials of the herbicide Simazine and fertilisers (Ground Mineral Phosphate and 'Nitrochalk') were included. The work done by the Wilder Rainthorpe Chopper is shown in our Plates.

Preliminary Assessments

Prior to siting the plots, two maps of peat depth (in 6-inch classes) and dominant tree height (5-ft. classes) were prepared on the basis of a 1 × 2 chain grid covering the six compartments which had been selected for uniformity of crop and aspect. (A broad correlation between peat depth and tree height was noted). A third map recording roads, racks, main drains, younger crops, gulleys, drains, windthrow and main slopes, was prepared, and felling areas were then selected, as far as possible at random, to have comparable margin characteristics and to avoid any recognisable features influencing the stability of the crops; i.e. the aim being to isolate the factor of clearing size. In addition, a systematic sample of trees was pulled over alternately in opposite directions near the proposed margins of the 10-acre clearing and some others as an attempt to predict areas of potential weakness. Having correlated soil and root type, tree pulling was discontinued and the windthrow susceptibility assessment was completed on the basis of soil pits dug on the perimeter at N, S, E and W of each 0·1 acre area and at eight points on the larger clearings.

Later Assessments

Since the areas were felled in the winter of 1961/62, various effects have been observed and assessed. These include the windrun within a sample of clearings, measured at mid-crown height with cup anemometers fixed to masts at the centre of each clearing, retained for this purpose; the occurrence of

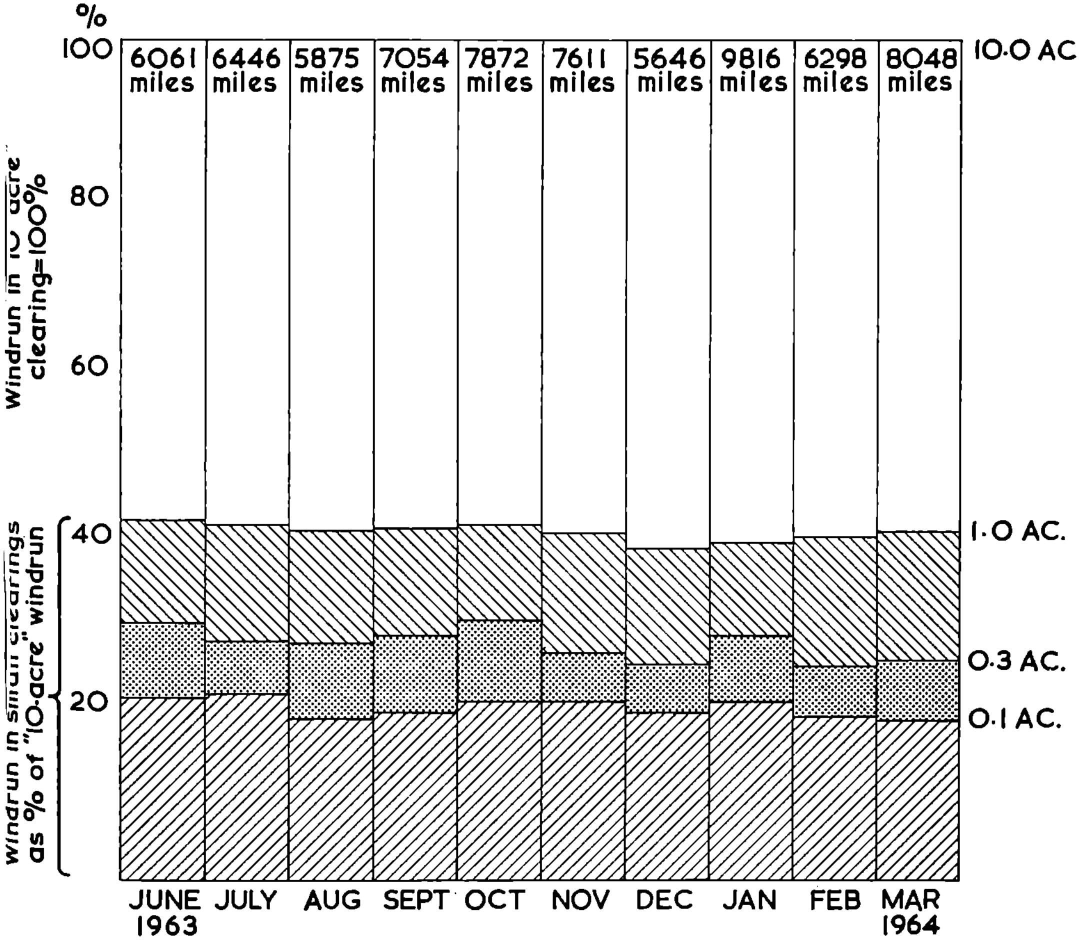

FIGURE 13. Windrun in small clearings in relation to windrun in a 10-acre clearing measured at mid-crown height.

windthrow (each tree classified by compass direction, peat depth and tree height); and the growth and survival of the replanted species with and without fertiliser. The results are summarised separately below.

The measurement of windrun during a particular span of time is considered to give a reasonable measure of the relatively greater reduction in mid-crown wind speed due to the smaller size of certain clearings. No measurements of windrun were taken in unfelled plantations, nor in the open; and there were no measurements at wind direction, except at Eskdalemuir.

Stability of Margins

It can be seen from Figure 13 that there is a consistent reduction in windrun with decreasing size of felling area, i.e. the edge trees of the smaller plots are apparently subjected, at the critical heights, to less wind. The proportional reduction is notably constant in spite of considerable variation in windiness over the period during which records were taken. (Topographical variation seems to have little effect over the experimental site as two 1-acre plots sited in different compartments gave very similar results).

Table 28

OCCURRENCE OF WINDTHROW, MAY 1962 TO MAY 1963

Plot Size (No. of plots)	10 acre (1)	1·0 acre (3)	0·3 acre (3)	0·1 acre (10)
Windrun* (miles as % of windrun in 10 acre plot) No. of anemometers	100% (1)	41% (2)†	28% (1)	20% (1)
Ratio of Perimeter per acre felled	1	3	5	7
No. of trees Windthrown per acre in the year May 1962—May 1963	117	145	164	281‡

* Assessment period June 1963—March 1964.
† Second anemometer assessed variation due to location and topography.
‡ Corrected to exclude two plots damaged by extraneous factors.

Table 28 shows that although less windrun was recorded in the small clearings this was not reflected in smaller numbers of windthrown trees on an acreage basis; the greater length of perimeter per acre felled having outweighed the apparent reduction in wind speed.

In order to get a picture of the relationship between the number of trees blown on each sector of the felling areas and the force and direction of the wind causing the damage, records of windthrow from the 0·1 acres plots only have been used, since these plots are the best-replicated, and, because of their small size, most effectively sited to secure uniform edge conditions.

Errors of observations from all the sectors of the margin of a plot are assumed independent in the analysis, for simplicity. This certainly results in too high a calculated significance, and this must be allowed for in the interpretation. Transformation to logarithms, of the numbers of trees damaged in each sector, improves the applicability of the model as it seems more reasonable to assume proportional variations in damage rather than additive ones. Figure 14 shows the average number of trees damaged in each sector determined from the

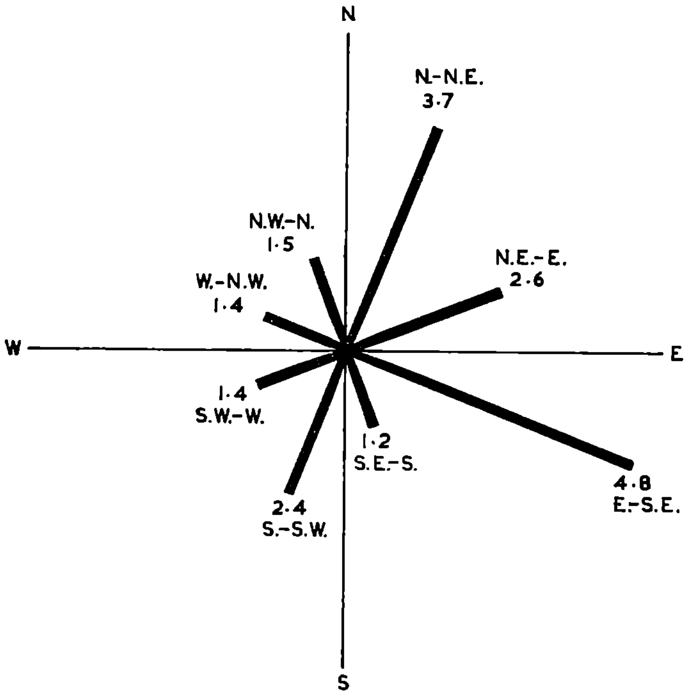

FIGURE 14. Diagram showing trees blown on each 45° sector in one-tenth acre plots in the Forest of Ae.

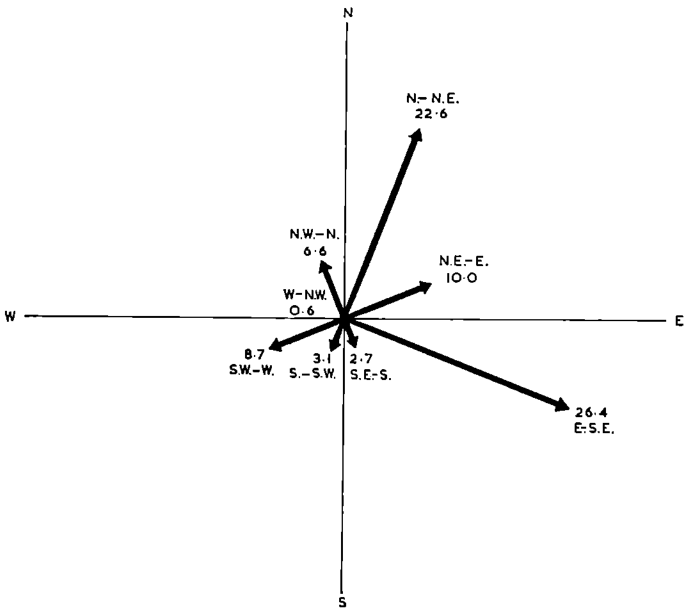

FIGURE 15. Diagram showing wind values (W = duration of wind × highest gust) summed over period for each 45° sector at Eskdalemuir (See *Note* in text).

0·1-acre plots, excluding C5, C6 and C14 which were spoilt by extraneous factors.

A simple and somewhat arbitrary expression of wind force has been used. After each damaging gale, records were obtained from the nearest meteorological station, Eskdalemuir, approximately 30 miles away to the east. Each damaging gale was 'measured' as the product of the speed of the highest gust and the time (to the nearest day) the gale lasted. These wind 'values' were taken to be acting over the full arc through which the gale varied, but not outside it. The values were calculated for 10° intervals, and summed for the period of observations over each 45° sector. Figure 15 shows the result.

Comparing Figs. 14 and 15, it is clear that on this site trees were blown out of the plots in the direction of the wind. There has been virually no damage on lee margins, hence there is no support for the idea that trees are 'sucked' into gaps on any important scale. The number of trees blown on any sector are clearly related to the 'quantity of wind' that was apparently blowing against that sector, here measured by the arbitrary expression *W*. No doubt with more adequate local information an expression of wind could be found which would show (for this particular site) a closer quantitative relationship with trees blown.

The plots differ very significantly in the average susceptibility of their margins, but regressions on the tree height and peat depth indicate that little of this variation can be associated with either factor. However, the estimates of tree height used were very crude and possibly rooting depth (which was not assessed) rather than peat depth might have been more meaningful. Hence the influence of tree height and rooting depth has not been adequately tested. The preliminary assessment of stability by tree pulling classified all perimeters except two small sections of the 10-acre area as unstable, and it has not been possible to correlate windthrow with this assessment.

There were at least nine gales which did appreciable damage in the year under review and these included all gales recorded as having a mean speed of forty miles per hour at Eskdalemuir, plus several lesser ones. The main winds damaging the experiment in this year came from SW and NW, which agrees broadly with long-term local experience.

Note: This 'windrose' shown in Figure 15 is contrary to the normal pattern viz. the value of the wind hitting a particular 'face' is shown, rather than the direction from which that wind came. This arrangement provides a more logical comparison with Figure 14.

Survival and Early Growth of the Second Crop

First year survival of both Norway and Sitka spruce varied significantly with felling area size. But, as the survival ranged from 91% in the ten-acre clearing to 98% in the tenth acre clearing, the practical importance of this difference is small, especially as the season after planting was exceptionally dry.

Both species suffered a post-planting check in the first season. Sitka spruce remained green and began to grow rapidly in the second year. Norway spruce turned yellow in the first year and its colour improved in the second without much shoot growth. This pattern is repeating itself in the later planting years.

Sitka spruce in many 0·1 acre clearings is noticeably finer-needled than in larger clearings and this has been confirmed by quantitative assessment. There is a tendency for individual needle weights in the northern half of the smallest clearings to be heavier than needle weights in the southern half. It appears, therefore, that Sitka spruce in the smaller plots is receiving insufficient light, but the effect of this on height increment has not been demonstrated as height growth has not yet been assessed.

Natural regeneration of Sitka spruce has been sufficiently prolific to justify further investigation.

Re-invasion of Vegetation

Plans for vegetation assessment and time-studied weeding have proved unnecessary. Two summers after felling, weeding has only been necessary on areas previously carrying open wind-damaged crops where vegetation was already established. On the remainder of the area vegetation colonization is in the region of 10%, and hence the minor herbicide trial has been irrelevant. This was totally unexpected. Previous regeneration trials were sited on wind-damaged open crops where massive re-invasion of grasses necessitated costly weeding in the second and third years.

Use of Fertiliser

Not surprisingly there has been no response to phosphatic manure after two growing seasons—the previous crop having reached Quality Class IV without additional phosphate.

Applications of 'Nitrochalk' intended to 'boost' replanted trees through the weeding stage have also not affected growth in the first season.

Discussion

This experiment has been the first involving experimental clear-felling on a fairly large scale. Its objects were ambitious and in spite of many methodological sources of error, it has produced most interesting results. *It must be emphasised* that inadequate replication in time and place make this trial much more of a sighting shot than a definitive experiment, and that the 32 to 35-year-old, Quality Class IV, Sitka spruce crop in which the experiment was sited most certainly presents features untypical of a maturer stand.

In brief, the indications arising from this experiment are:—

(1) The windrun within clearings, measured at mid-crown height, and hence considered to hit windward margins, is dependent on the size of the clearing; the smallest clearing had the least run of wind.

(2) The reduced amount of wind damage in small fellings that might be expected from the above reduction in wind speed is outweighed by the much greater length of perimeter at risk.

(3) Although significant differences in survival of replanted trees were noted between clearing sizes, they were not on an important scale.

(4) Vegetation re-invades a clean area at a geometric rate. It appears that immediate replanting of some quick-starting species (e.g. Sitka spruce, Western hemlock) may avert the necessity to weed, hence there may be an advantage in clearfelling wind-battered stands back to a suitable margin (natural or artificial) before a grass vegetation is established, rather than wait for the wind to flatten a sizeable area.

Because of extending windthrow, which invalidates the original classification of plot sizes, and the merging of plots, etc., the effective life of this experiment will probably not exceed a total of 10 years. In addition, roe deer damage in the 10-acre clearing may well invalidate early height growth comparisons. A further experiment is proposed in order to test the results of this preliminary investigation. General views of the experiment appear in our Plates.

RESULTS OF SOME OLDER SCOTS PINE PROVENANCE EXPERIMENTS

By R. LINES and A. F. MITCHELL

The earliest provenance experiments established by the Forestry Commission were planted in 1928 at Inchnacardoch, near Fort Augustus, Inverness-shire and at Teindland, near Elgin, Morayshire. They were followed by further experiments at Inchnacardoch in 1929 and 1931, at Findon in the Black Isle Forest, Ross-shire in 1929, at Roseisle, Morayshire in 1930 and 1935 and at Thetford, Norfolk in 1932–33. In all, about 90 individual seed lots are represented, but several of the experiments were not designed in such a way as to permit statistical analysis, so that gross differences between provenances are necessary before clear distinctions can be drawn. It is known that site differences within an experiment are often greater than provenance differences.

These early experiments include a wide range of Continental provenances, from northern Finland to Spain, and as far east as the Ural mountains of Russia. They also include a fairly comprehensive collection from the remnants of the old Caledonian Forest of Scotland. The provenances are listed in Table 39.

Teindland Forest, Experiment 32 P.28

This experiment is on a fairly good site for Scots pine and was planted with eight provenances, each replicated three times, in plots of 300 plants. As noted by Edwards (1953) the early growth and survival of the Finnish provenances from Ahtari (62½°N) and Kittila (67½°N) was very poor, and after three years, two of the Kittila plots and one of those from Ahtari were re-planted with a Scottish provenance from Loch Maree in Wester Ross.

The experiment was measured for height at the ages of 6, 13, 18, 20 and 33 years (Table 29) and it is interesting to note that the relative position of the provenances has changed little over this period. The Kittila (Finland) provenance had so few survivors that it was not assessed for height at 33 years. The Ahtari (Finland) provenance was markedly less tall than the remaining ones, which do not differ significantly in height, though the Scottish provenances are on the whole taller than the foreign ones.

The Vyborg (Valkjarvi) provenance comes from what is now Russian territory on the north of the Gulf of Finland, and the seed was supplied by the Finnish authorities about 1930. (Vyborg is also called Viborg or Viipuuri). This provenance is notable for combining fair height growth with the good stem and crown form associated with northern provenances of Scots pine. Plus trees have been selected in a plot of this origin and in one of the Ahtari (Finland) plots.

The Teindland experiment was badly damaged by the gale of January 1953, in which 342 trees were blown. As a result one of the main Latvian and two of the 'Riga, Latvia' plots were abandoned; they were not the tallest plots in the experiment. Of the remaining plots, the provenances with the greatest total basal area production (standing crop, thinnings and windthrows) were the two Scottish provenances (Table 29). The very poor increment on the two surviving Ahtari plots, and the appreciably lower increment on the Viborg provenance, show clearly the loss in volume production that would result if these northern provenances were to be used more widely.

The appearance of the two Latvian provenances ('Latvia' and 'Riga, Latvia') has raised some doubt as to their authenticity in the minds of Continental visitors. German and Swedish experts on Scots pine who have seen these origins do not believe Id. No. 25/67 and Id. No. 28/501 to be true var. *rigensis*, though there could be a greater variation in provenances from Latvia than is commonly supposed.

Experiment 32 is currently suffering from an attack of the Pine stem rust *Peridermium pini.* This was first noticed in 1958 and since then more than 100 badly infected trees have been cut out, while fresh infections are still occurring. This fungus generally infects vigorous dominant trees, rather than weakly sub-dominant or suppressed ones. Careful records of the progress of the attack show that there is no correlation between growth vigour of the provenances and the number of infected trees; thus the worst attack is on the fast-growing Loch Maree (Scotland) and the slow-growing Ahtari (Finland) provenances, while the Beaufort (Scotland) and 'Riga, Latvia' ones are only slightly affected (see Table 29). The figures in the final column include both current infection and trees already removed.

Table 29

HEIGHT, TOTAL BASAL AREA AND PERIDERMIUM ATTACK AT TEINDLAND. EXPERIMENT 32 P.28

Identity No.	Provenance	Height in feet at age in years					Total Basal Area Sq. ft. at 33 years	Total No. of trees with *Peridermium* per acre
		6	13	18	20	33		
25/69	Kittila, Finland	N.A.	N.A.	N.A.	7·3	N.A.	N.A.	60
26/F.8	Ahtari, Finland	1·2	5·3	8·3	9·9	31·5	89	150
25/27	Viborg, Finland	2·1	8·4	12·3	14·5	35·2	120	83
28/501	'Latvia'	2·6	10·2	16·3	18·2	38·2	160	70
25/67	'Riga, Latvia'	2·5	9·6	14·5	16·3	36·0	128	20
25/503	Pitgaveny Estate, Scotland	2·3	9·1	14·6	16·8	37·7	168	80
25/502	Beaufort Estate, Scotland	2·9	10·3	16·1	18·5	38·9	198	40
25/25	Haguenau, Alsace, France	2·2	9·1	13·9	16·1	37·1	140	63
29/547	Loch Maree, Scotland	N.A.	4·5	8·8	10·5	34·5	120	160
	,, ,, ,,	—	(7·0)	(12·5)	(16·0)	(40·0)	(140)	

Notes. 1. 'Loch Maree' was planted three years after the others; the figures in brackets give the calculated height and basal area at the ages shown.
2. N.A. = Not assessed.
3. The badly wind-damaged plots of Latvia and Riga are excluded.

Inchnacardoch Forest, Experiment 58 P.28

This experiment contains four of the same provenances, namely Kittila and Viborg from Finland, the supposed Latvian provenance Identity No. 25/67, and Haguenau, Alsace. It is on a moderately good pine site (Quality Class II) and there are four replicates of 49 plant plots. Edwards (1952) noted the early failure of the Kittila provenance, which comes from Finnish Lapland, and

Table 30

HEIGHT, PERCENTAGE OF CLASS I STEMS AND VOLUME PRODUCTION AT INCHNACARDOCH, EXPERIMENT 58 P.28.

Identity No.	Provenance	Height in feet at age in years					Percentage of Class I stems		Volume per acre cu. ft.	
		5	8	18	22	35	22 yrs.	35 yrs.	Standing	Total
25/69	Kittila, Finland	1·0	1·6	(5·3)*	—	—	—	—	—	—
25/27	Viborg, Finland	2·1	4·7	18·0	24·5	38·1	52	29	1,500	2,550
25/67	'Riga, Latvia'	2·6	5·8	20·4	28·9	40·0	12	5	2,100	4,000
25/25	Haguenau, Alsace, France	2·3	5·2	20·4	26·7	42·6	41	24	2,200	3,950

Note. * 50% failures, remainder unhealthy or dying.

the poorer height and girth of the Vyborg (Russia) origin compared with the more southerly ones at the age of 22 years. A final assessment in November 1962, when 35 years old, showed (Table 30) that the only difference during the 13-year interval was that Haguenau and 'Latvia' had changed places in ranking. The percentage of Class I stems in the dominant and co-dominant canopy classes showed the same poor form on the Latvian provenance, though it would appear that either the trees had deteriorated in form or that the standard of scoring differed between the two assessments. Three thinnings were carried out between the two assessments and the table shows the standing volume at 35 years and the total volume production including four thinnings. The poor production of the Vyborg provenance is again evident. The poor stem form and general appearance of the Latvian provenance cast considerable doubt on its identity.

Findon, Experiment 1 P.29, Black Isle Forest, Easter Ross

The design of this experiment (five replicates of 30 plant plots with unreplicated plots, mostly about half an acre in size, surrounding them) enabled fairly precise statistical comparisons to be made of early growth, while the Sample Plots laid out in the larger plots have now been measured four times.

Fourteen seed origins were planted, including four Scottish ones, which may be true provenances, one from plantations in East England, five from Finland, one from Latvia, two from Russia and one from Spain. This rather miscellaneous collection omits those Continental provenances which are now accepted as fast-growing, and the first report on this experiment at the age of 22 years (Edwards, 1953) showed that there was a clear distinction in height growth between the home provenances and the foreign ones. The appearance of the Latvian provenance from Selburg is similar to that of the Finnish origins and there is no reason to doubt its authenticity.

An intermediate report on this experiment was published by Robertson (1959) giving the results up to the age of 29 years. It was noted that due to probable interference between the small plots, any height assessments made in them after 22 years would be liable to error. Nevertheless, it was decided to assess the two tallest trees in each of the replicated plots at 30 years and again at 35 years, to see whether such interference between plots was apparent. The sample of two trees per plot gives the appropriate 'Top height' (i.e. the height of the 100 trees of largest girth per acre). Table 31 shows that the 'Top height' in the unreplicated plots was always less than that in the Sample Plots at the same age, but that there was a close parallel between the ranking of the provenances. This suggests that this type of experimental design may give valid results for a longer period than is normally assumed. The better height growth in the Sample Plots is almost certainly due to better site conditions.

The volume production of the "East England" origin was the highest of the home lots, but its form was not so good as that of the slightly slower Strath Conon provenance at 29 years of age. The percentages of Class I stems in the "East England" origin was higher than the others at the first assessment at 23 years. It fell at the second and third remeasurements, but only the thinnings were classified at the fourth (intermediate) remeasurement so that one cannot say if this trend continues.

The overall result is that the home lots have proved clearly superior to any of the Continental origins, of which the best was the Raivola provenance

Table 31

HEIGHT, VOLUME AND STEM FORM AT FINDON EXPERIMENT 1, P.29

Identity No.	Provenance or Origin	Small Replicated Plots: Height in feet at age in years			Sample Plots: Top Height in feet at age			Sample Plots: Volume cu. ft. aged 35		Sample Plots: % of Class I stems at	
		22 Mean	30 Top	35 Top	23	29	35	Standing	Total	23 yrs.	29 yrs.
25/505	Strath Conon, Scotland	20·1	31·7	36·6	30½	37½	44	1,893	2,606	38	15
26/502	Innes, Scotland	22·0	32·9	38·2	32½	40	46	1,913	2,649	9	2
26/501	Darnaway, Scotland	21·0	31·9	38·3	32	38	44	1,848	2,422	24	5
25/504	Loch Fyne, Scotland	19·5	32·4	35·2	28	35	42	1,693	2,061	23	5
26/17	'East England'	22·5	35·1	40·4	33½	40	46	1,989	2,893	43	10
26/F6	Sodankyla, Finland	Mainly dead	Mainly dead	Mainly dead							
26/F7	Pieksamaki, Finland	8·8	19·4	23·7							
26/F8	Ahtari, Finland	12·4	25·3	28·8							
26/F1	Evo, Finland	10·2	22·4	26·9	—	—	36½	1,110			
26/F3	Raivola, Finland	14·5	27·0	31·8	—	—	40	1,500			
26/54	Selburg, Latvia	10·0	16·0	19·3	—	—	36	980			
25/70	Ural Mountains, Russia	(7·4)	18·0	20·6							
26/4	Borzhom, Caucasus, Russia	9·6	21·5	26·0							
26/9	Sierra Nevada, Spain	(4·8)	(10·7)	(12·8)							

Notes. 1. Heavy failures in provenances with bracketed data.

2. The extensive plots from Evo, Raivola and Latvia are not true Sample Plots; they originally contained many beat-up plants of Lodgepole pine, now mostly cut out.

from Southern Finland. This was not very much poorer in height growth than the Loch Fyne provenance, though its standing volume was appreciably lower. Early survival was poorer in the Raivola plots than in any of the home lots and it experienced rather heavy losses in the extensive plot (26% after five years).

In the first report on the experiment, Edwards noted the common belief that the 'East England' pine derived from Scottish sources. This particular collection (26/17) of over 6,000 lbs. of seed must have come from a range of stands and it is probable that a fair amount came from the Scots pine 'hedges' of the Breckland district in Norfolk and Suffolk (East Anglia). There is some doubt about the Scottish origin of these.

Inchnacardoch Experiment 84 P.29

The experiment can be considered as another replicate of the Findon one, on a difficult peat site in a region of moderate rainfall, and with a different design. The provenances were planted in groups (i.e. 21 plants at 2 to 4 ft. apart within the groups) which are spaced 24 ft. apart between centres (Anderson, 1930). The groups occur on three morainic knolls covered with *Calluna/Trichophorum* vegetation, usually giving three replicates; or in some cases two groups of one provenance occur on the same knoll. Additional provenances from 'West Norway' and from five Scottish districts were added in 1931. The planting method was into a shallow turf, or direct notching where the peat was too thin.

The experiment was assessed in January 1961 for the height of the two tallest trees per group. The stem class was recorded for all trees (except those marked as thinnings) and the survival percentage was calculated.

The percentage of trees in each of the stem classes was multiplied by a weighting factor (Class 1 × 3, Class 2 × 2 and Class 3 × 1) to give a total stem class score.

It is clear from Table 32 that the Scottish and 'East England' group of provenances were best for height and survival, and intermediate in stem form between the Fenno-Scandinavian origins and those from the rest of Europe, and this is shown in Figure 16. It might be expected that poor survival would result in poor stem form, but there seems to be little evidence for this from Table 32, except where survival was below 25%. As in the other experiments, the supposed Latvian provenance 'Riga, Latvia' 25/67 grew more vigorously than the undoubted Latvian provenance 26/54, whose few survivors nevertheless had superior stem form.

Plots planted in 1931 were given phosphate fertiliser at planting, while the earlier plots were not manured until they were 10 years old. This probably accounts for the better height growth and survival of the younger trees and may also be the reason for their better stem form. For this reason they have been excluded from Fig. 16. As the experiment was not laid out with statistical analysis in mind, it is not legitimate to apply statistical tests to the results from this non-orthogonal design.

Inchnacardoch, Experiment 92 P. 31–35

This collection consists of a wide range of Scottish and some foreign provenances and was originated by Professor M. L. Anderson, who collected much of the seed himself. He chose the Inchnacardoch site because it was a district of moderate rainfall (45–50 ins.) 'so that the races from wet and dry areas

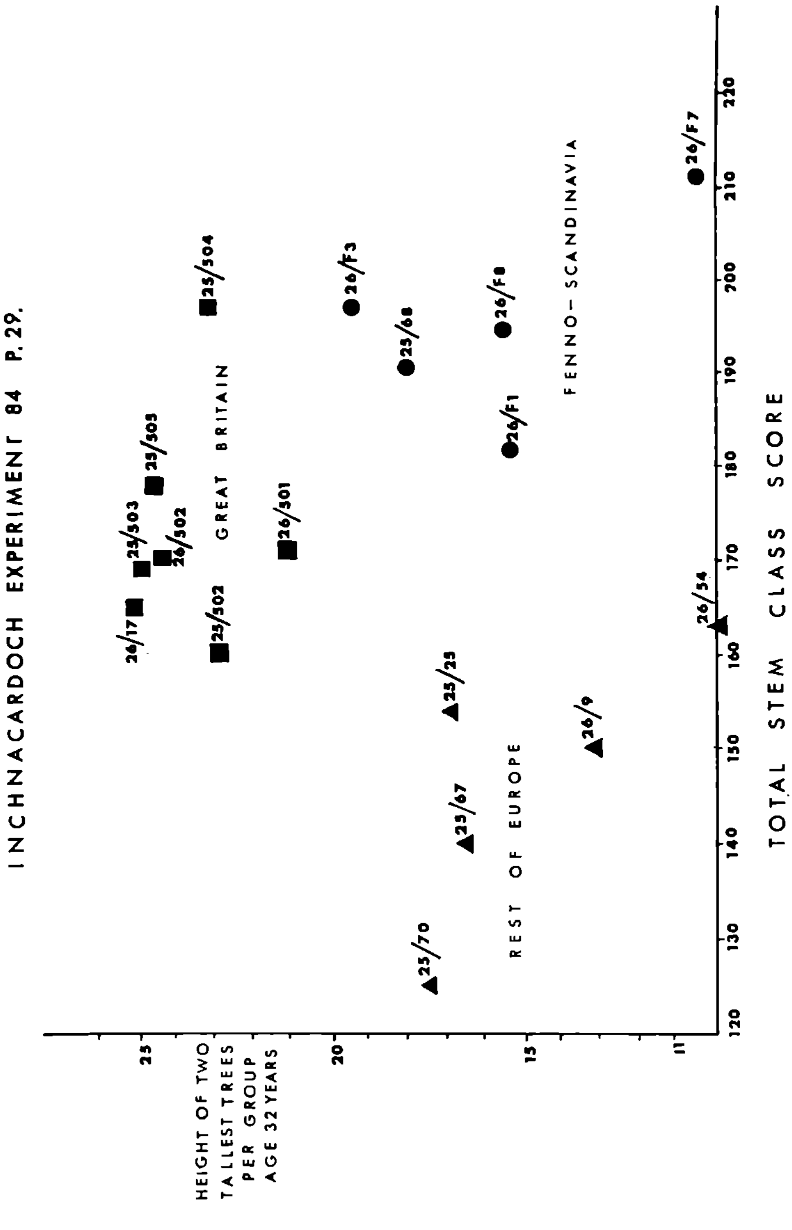

FIGURE 16. Heights and stem class scores for Scots pine of various provenances.

Table 32

HEIGHT, STEM FORM AND SURVIVAL % AT INCHNACARDOCH, EXPERIMENT 84 P.29.

Identity No.	Provenance or Origin	Height of 2 tallest trees per group, ft.	Total stem class score	Survival %
Planted 1929 Age 32 yrs.				
25/505	Strath Conon, Scotland	24·8	178	64
26/502	Innes, Scotland	24·7	170	84
26/501	Darnaway, Scotland	21·5	171	81
25/504	Loch Fyne, Scotland	23·3	197	65
26/17	'East England'	25·2	165	52
25/502	Beaufort, Scotland	23·0	161	79
25/503	Pitgaveny, Scotland	25·0	169	59
25/68	Alvsby, Sweden	18·1	191	62
26/F6	Sodankyla, Finland	Mostly dead	—	—
26/F7	Pieksamaki, Finland	10·5	211	36
26/F8	Ahtari, Finland	15·6	195	54
26/F1	Evo, Finland	15·3	182	43
26/F3	Raivola, Finland	19·6	197	55
25/67	'Riga, Latvia'	16·5	140	27
26/54	Selburg, Latvia	(10·0) (Many dead)	163	14
25/70	Ural Mountains, Russia	(17·3) (Many dead)	125	13
25/25	Haguenau, Alsace, France	17·0	154	38
26/9	Sierra Nevada, Spain	13·3	150	26
Planted 1931 Age 30 yrs.				
26/503	'West Norway'	15·6	205	42
29/547	Loch Maree, Scotland	27·5	208	79
29/554	Glen Moriston, Scotland	26·1	221	89
29/549	Abernethy, Scotland	25·0	198	78
29/559	Darnaway, Scotland, 70 yr. trees	24·9	192	94
29/560	Darnaway, Scotland, 18 yr. trees	28·0	211	92

may have a fair chance'. A 20-acre area of *Calluna* moorland was marked off into square chain units and these were sub-divided to give four plots each of 64 plants. Unfortunately, the plan for the experiment did not stipulate that the provenances should be randomised, so that in practice each provenance was planted in the four plots of the square chain. This has now resulted in square chain plots, as the individual 64-plant plots have joined across the alleys, but no statistical estimate of the variation due to site is possible. In the later years, some pairs of plots were laid down in a randomised design with two or at most three replications, but this only applied to some of the provenances and others are represented only by a single 64-plant plot. Fertiliser has not been applied and the trees were notched into the soil with no other cultivation. Growth has been irregular within the plots and appears to depend on the depth of the pan, which subsequent trenching has shown to fluctuate in depth over short distances.

Table 33

HEIGHT, INCREMENT AND STEM FORM IN INCHNACARDOCH, EXPERIMENT 92 P.31

Identity number	Provenance	Rain-fall	Height in feet at 22 yrs.	Height in feet at 26 yrs.	Periodic Annual Increment ft.	Stem form in 1957	Notes
Planted 1931	*Scotland*						
29/547	Loch Maree	H	14·1	24·3	2·6	Fair	
29/549	Abernethy	M	16·2	25·0	2·2	Fair	
29/554	Glen Moriston	M	19·9	27·2	1·8	Good	
29/559	Darnaway 70-yr. trees	L	24·5	32·6	2·0	Good	Some windthrow
29/560	Darnaway 18-yr. trees	L	23·3	33·0	2·4	Good	Some windthrow
	Others						
26/503	'West Norway'		9·4	15·9	1·6	Poor	Few survive
26/F6	Sodankyla, Finland		failed	—	—	—	—
26/F7	Pieksamaki, Finland		18·8	27·7	2·2	Fair	Poor crowns
26/F8	Ahtari, Finland		14·5	18·2	0·9	Good	
28/52	Vyborg, Russia		19·8	25·4	1·4	Fair	Poor crowns
27/502	Sweden, var. *lapponica*		13·2	18·3	1·3	Poor	Perhaps the same as 25/68 at Inchnacardoch 84
28/19	Västeraas, Sweden		22·4	27·3	1·2	Good	Fine branching
28/18	Latvia, var. *rigensis*		24·2	30·6	1·6	Good	Fine branching
27/501	Caucasus, Russia, var. *hamata*		22·2	26·7	1·1	Bad	Perhaps the same as 26/4 at Findon
28/31	Sierra Nevada, Spain		15·8	22·3	1·6	Bad	Many deaths, cankered
Planted 1932	*Scotland*						
29/534	Glen Mallie	H	24·3	32·9	2·2	Fair	
29/544	Glen Uig	H	25·4	34·1	2·2	Fair	
29/546	Shieldaig	H	22·3	29·4	1·8	Fair	
29/545	Coulin	H	27·0	36·3	2·3	Good	
29/548	Rhidorroch	H	18·2	26·4	2·1	Fair	
29/535	Loch Tulla	H	24·7	32·3	1·9	Fair	
29/531	Glengarry	M	20·8	28·0	1·8	Fair	
29/532	Inchnacardoch	M	20·8	29·2	2·1	Fair	
29/553	Glen Moriston	M	22·0	32·2	2·6	Fair	
29/506	Balmacewan	L	25·6	36·0	2·6	Fair	

29/550	Glen Tanar	L	22·1	30·5	2·1	Fair	Rather coarse branching
29/551	Glen More (Cairngorms)	L	17·2	25·7	2·1	Poor	Coarse branching
29/552	Ballochbuie	L	26·2	34·1	2·0	Good	
29/556	The Bin	L	25·7	34·0	2·1	Good	
29/557	Altyre	L	22·7	31·4	2·2	Fair	
30/556	Haddo House	L	26·0	32·7	1·7	Fair	
	Others						
30/525	Dalecarlia, Sweden		12·4	16·3	1·0	Good	Unhealthy
30/549	West Norway		17·4	25·7	2·1	Good	Fine branching
30/56	Lenti, Hungary		16·0	23·9	2·0	Poor	Unhealthy
30/57	Sopron, Hungary		18·4	24·6	1·6	Poor	Some canker
29/505	Auvergne, France		17·6	25·7	2·0	Poor	Unhealthy
Planted 1933	*Scotland*		20 *yrs.*	25 *yrs.*			
30/539	Abernethy	M	—	28·0		Good	Poor crowns
30/547	Darnaway 160-yr. trees	L	23·1	33·0	2·0	Good	
30/554	Darnaway, general collection	L	26·2	32·2	1·2	Good	
30/555	Darnaway, general collection	L	25·3	34·8	1·9	Good	
31/1031	Cawdor	L	20·0	30·5	2·1	Good	Fine branching
	Others						
31/1040	Allenstein (East Prussia) now Poland		15·0	24·4	1·9	Fair	Many deaths, some canker
31/1012	Herselt, Campine, Belgium		16·6	24·2	1·5	Fair	Uneven, some canker
Planted 1935	*Scotland*		18 *yrs.*	25 *yrs.*			
33/509	Glen Uig	H	23·5	36·4	1·8	Good	
32/539	Achnashellach	H	18·5	29·8	1·6	Good	
32/511	Glen Mallie	H	21·4	34·0	1·8	Good	
32/515	Strathoykell	H	20·9	34·4	1·9	Fair	
32/510	Glengarry	M	19·2	30·9	1·7	Fair	
32/508	Rannoch	M	12·9	24·8	1·7	Fair	Damaged by deer
32/538	Glenmoriston	M	18·8	30·7	1·7	Good	
32/512	Inchnacardoch	M	17·6	26·9	1·3	Good	Very irregular
32/509	Darnaway	L	18·0	27·3	1·3	Fair	
53/517	Altyre	L	14·8	23·0	1·2	Good	
	Others						
32/540	Västeraas, Sweden		14·9	25·9	1·6	Good	Mostly healthy
32/530	Hedmark, Norway		8·5	14·0	0·8	Poor	Mostly unhealthy
32/518	(East Prussia), Now Poland		17·6	28·4	1·5	Fair	Uneven growth
32/524	Hanau, Germany		13·2	21·6	1·2	Poor	Many unhealthy
35/520	Auvergne, France		10·4	17·0	0·9	Poor	Coarse and unhealthy

Table 33 lists the provenances and gives their heights at 18 to 22 years and at 25 to 26 years, together with notes on stem form and other characters. The earlier height assessment was made on the basis of the tallest two trees in each row of eight, while the later figures are the mean heights of the three tallest trees per plot (approximating to the height of the 100 largest per acre). The difference between the two assessments therefore gives an over-estimate of height increment in absolute terms, but it does allow comparisons between provenances planted in different years. The summary in Table 34 shows the mean height increments for the different groups of provenances, the Scottish ones being divided into those from High (above 50 inches), Medium (40–50 inches) and Low (below 40 inches) Rainfall areas. It may be noted that nearly all the High Rainfall provenances were from relict native stands, while the Low Rainfall provenances were largely from private estates well known for their Scots pine plantations.

The design of the experiment does not justify firm conclusions, but it is clear from the original vegetation chart, and notes on the establishment of the experiment, that bias was not introduced by planting the foreign provenances on the poorer parts of the site, in fact the plots on the areas marked as 'wet hollows' on the original map have grown as well as those on adjacent *Calluna* moor. It can be concluded that on this relatively poor site (a) a very wide range of provenances can be established, from as far as 62½°N in Finland to 37°N in Spain and as far east as the Caucasus Mountains. Origins from further north in Finland and Sweden were virtual failures and southern provenances (Spain and Auvergne) did badly. (b) Reputed fast-growing provenances (e.g. Hanau, Herselt) from middle latitudes of Europe were mediocre in performance. (c) The Scottish provenances were superior to all others in height increment, though they did not have such good form as some of the better north European lots. The high rainfall provenances had a marginally better rate of increment, but due to the poor experimental design these results must be treated with caution.

Roseisle, Experiment 2, Planted 1930/31

This experiment was planted with five Scottish provenances and one from 'West Norway'. The latter grew poorly and had so many deaths, that it must be regarded as a total failure. The site is a coastal sandy flat, originally covered in grass, and was ploughed in bands before planting in Anderson groups of 13 plants, each provenance being represented by twenty groups suitably randomised. In 1930 one-year seedlings were used, and the following year a further ten replications of the same provenances were added as 1+1 year transplants. Edwards (1953) showed that the Darnaway provenances were the tallest in both seedling and transplant sections at 17/18 years, and this was still true after 28/29 years, although the differences, both between seedlings and transplants and between provenances, had become very small. However, the basal areas of the crop before thinning showed highly significant differences between the provenances, with the Darnaway provenances clearly superior to those from Glen Moriston, Abernethy and Loch Maree, also in Scotland.

The spaced-group method of planting was developed by Anderson (1930) who feared that the outer trees of the group might outgrow the inner trees, eventually suppressing them and thus forming a final crop of coarse, inferior stems. An assessment of the position of the two tallest trees per group shows

Table 34

PERIODIC ANNUAL HEIGHT INCREMENT OF PROVENANCES OF SCOTS PINE

FEET

Rainfall High Above 50 in.	*Scotland Rainfall Medium* 40–50 in.	*Rainfall Low* Below 40 in.	*Finland*	*Sweden*	*Norway*	*Latvia*	*France, Belgium, Germany*	*Remainder*
2·02	1·88	1·93	1·50	1·28	1·50	1·60	1·50	1·58
	Scotland 1·94			*Northern Europe* 1·43			*Middle Europe* 1·50	*Remainder* 1·58

that these tend to be located at the corners of the group, while central trees were generally co-dominants or sub-dominants (see Fig. 17). Partly due to this, the Scots pine in this experiment have developed many wolf trees and badly mis-shapen crowns are frequent. The overall appearance is much poorer than that of the surrounding plantations. An assessment of dominants and co-dominants for stem form in 1959 showed that the Abernethy and Glen Moriston provenances had the best stem form, while the two Darnaway provenances were markedly inferior (see Table 35).

Table 35

EIGHT, MEAN BASAL AREA PER GROUP AND STEM FORM AT ROSEISLE 2 P.30/31

Identity Number	Provenance (All Scottish)	Height of tallest trees per group at				Mean B.A. per group. sq. ft.	Percentage of Class 1 and 2 stems
		18 yrs. 1+0	17 yrs. 1+1	29 yrs. 1+0	28 yrs. 1+1		
29/554	Glen Moriston	16·4	17·3	33·3	34·6	0·60	81
29/547	Loch Maree	18·0	16·6	34·8	34·5	0·67	71
29/549	Abernethy	17·4	16·4	34·0	33·5	0·60	78
29/559	Darnaway, 70-yr. trees	18·6	19·4	35·0	36·3	0·85	63
29/560	Darnaway, 18-yr. trees	19·7	18·2	35·4	35·9	0·86	60

Notes (1) Heights at 17/18 yrs. are the mean of the three tallest trees per group.
(2) Heights at 28/29 yrs. are the mean of the two tallest trees per group.

Roseisle, Experiment 3, Planted 1935

This was laid out in Anderson groups, with four replications, on a similar site to that above. It contains twelve provenances, half from Scotland and the others from Germany, France and Norway. An assessment made at 13 years of age showed the tallest provenances to be those from Darnaway (which were one year older at planting) and Hanau. They were significantly taller than those from Altonside and Hedmark, and the latter had many failures. By 1959, when it was 24 years old, these height differences had become insignificant, nor was there a significant difference between provenances in the basal area per group. This was partly due to very wide variation in stocking of the groups within a provenance. The percentage of dominants and co-dominants which had Class 1 or 2 stems was higher in the Scottish provenances than in the foreign ones, the Haguenau was particularly poor in this respect. An assessment of the position in the group of the two tallest trees showed a similar result to that in Experiment 2. See Table 36.

Thetford, Experiment 18, Planted 1932–33

Of three experiments in England and Wales of this period, that at Thetford (Croxton Park) Experiment 18 is the only one which has survived to give useful information. This is fortunately in an area presenting the greatest contrasts in climate and soil to those in Scotland. The climate of the Thetford area is the nearest approach to a continental climate in these islands, having a

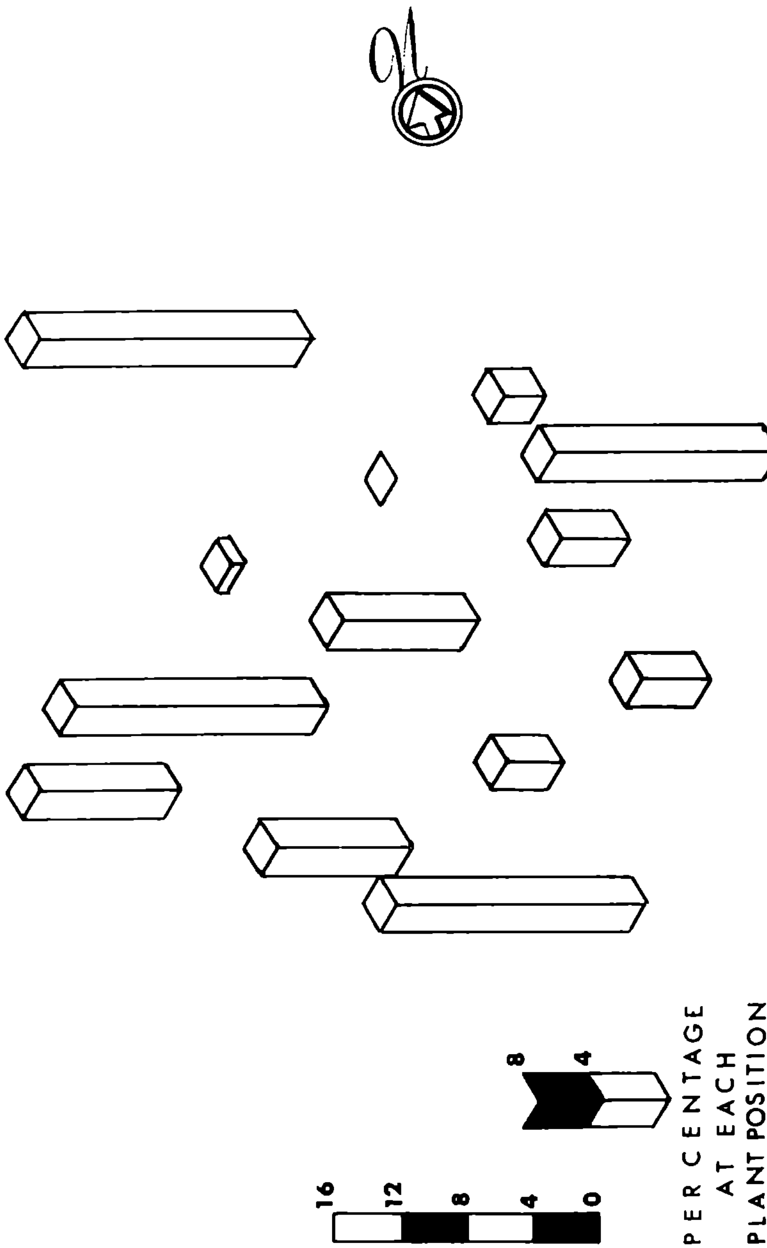

FIGURE 17. Distribution of Dominant and Co-dominant Scots pine trees within Anderson Groups at Roseisle Forest, Scotland.

Table 36

HEIGHT, INCREMENT, MEAN BASAL AREA PER GROUP AND STEM FORM AT ROSEISLE
Expt. 3. Planted 1933-35

Identity number	Provenance	Height in feet: 3 tallest per group 13 yrs.	Height in feet: 2 tallest per group 24 yrs.	Periodic Annual Increment ft.	Mean B.A. per group sq. ft.	Percentage of Class 1 and 2 stems
	Scotland					
32/508	Rannoch	10·5	31·3	1·9	0·70	69
32/510	Glengarry	10·0	31·8	2·0	0·58	82
32/511	Glenmallie	10·6	31·8	1·9	0·72	71
32/515	Strathoykell	10·8	30·5	1·8	0·70	79
32/535	Altonside	9·6	30·0	1·9	0·56	81
31/512	Darnaway	14·0	33·5	1·8	1·04	75
	Others					
32/530	Hedmark, Norway	(6·1)*	(29·0)*	—	(0·26)*	(50)*
32/518	(East Prussia)—Poland	11·2	29·8	1·7	0·64	54
32/1019	(East Prussia)—Poland	12·9	33·5	1·9	0·84	59
32/524	Hanau, Germany	13·4	34·0	1·9	0·80	40
32/517	Haguenau, France	12·1	32·5	1·9	0·47	0
32/520	Auvergne, France	10·3	29·5	1·7	0·40	45

* Few survivors

mean annual precipitation of 24 inches; long, cold winters with predominantly northerly and easterly winds; late springs with many hard frosts, and a relatively dry, warm summer. The soil is a light sand with flints and lies only twelve to twenty inches deep over chalky boulder-clay. The site was an arable field, and into this the first plants were notched in 1932, during a dry period followed by a hot, dry summer. Despite the weather, survival was good except in two provenances. There were nine provenances planted, with three replicates of each, placed at random but not in blocks. The provenances are:—the local Thetford collection; five from Scotland (Cawdor and Darnaway from the dry-zone in the north-east and Loch Maree, Glen Garry and Glen Moriston from the wet-zone in the north-west) two from Hungary (Sopron and Lenti) and one from north-eastern Italy (Trentino). In 1933, three replicates each of a further eight provenances were planted adjacent to and around the 1932 plots. These were from the Vosges (Hanau), and the Franco-German border (Wangenbourg), the German Plain across to Poland (Potsdam, Trottenwald and Allenstein), the Baltic (Riga and Valkjarvi, Russia) and Norway (Flak). Earlier reports on this experiment by Wood are in the Reports on Forest Research for 1949, 1950 and 1957.

These two parts of the experiment have no common provenance but the only difference between them is the one year in age. The analysed results are tabulated separately in Table 36, but by adjusting the figures from the younger series by the addition of one year's mean annual increment, a reasonably good comparison may be made, as in Table 37. This adjustment will slightly over-estimate the heights in the younger plots because current height growth is extremely slow, few trees of any plots retaining a dominant main axis. The mean annual volume increments are directly comparable, whilst survival percentages can be compared only with those planted in the same year.

Survival rates in the 1932 plots by the second year showed few significant differences, Trentino was very poor and Lenti rather poor, but the other Hungarian provenance, Sopron, compared favourably with the poorest of the Scottish, Loch Maree. Heights measured in these first plots at 18, 24 and 32 years show that on each occasion the provenances from Thetford, Sopron

Table 37

SURVIVAL, HEIGHT, GIRTH AND VOLUME AT CROXTON PARK, EXPERIMENT 18

	2 Years	18 Years	24 Years	32 Years			
Provenance or Origin	Survival (%)	Mean Ht. (Ft.)	Mean Top Ht. (Ft.)	Mean Top Ht.(Ft.)	Mean Top Girth (Inches)	Mean Total Vol. (Hoppus Ft.)	Mean Annual Vol. Incr. (Hoppus Ft.)
'East England' (Thetford)	90·7	27·0	36·5	45·0	24·0	2,500	78·3
Loch Maree, Scotland	66·5	23·7	32·0	40·7	24·2	2,093	65·0
Glen Garry, Scotland	91·8	21·3	30·7	39·7	25·2	1,843	57·5
Glen Moriston, Scotland	90·5	20·7	28·8	38·3	22·5	1,700	53·0
Cawdor, Scotland	88·4	25·0	34·0	45·0	23·5	2,267	71·0
Darnaway, Scotland	81·8	24·0	32·3	42·3	24·2	2,187	68·0
Trentino	25·2	22·7	31·7	43·0	29·0	1,697*	53·0
Sopron, Hungary	73·5	26·0	34·2	45·3	25·7	2,627	82·0
Lenti, Hungary	48·5	24·0	32·5	42·7	29·0	1,883	58·9
S.E.	—	0·95	0·97	1·00	—	206·7	
L.S.D.5%	—	3·1	3·2	3·3	—	674	
L.S.D.1%	—	4·5	4·6	4·7	—	—	
	1 Year	17 Years	23 Years	31 Years			
Hanau, Germany	83·1	26·0	37·3	47·0	26·8	2,783	89·7
Wangenbourg, France	73·8	26·3	36·7	47·0	25·7	2,850	92·3
Trottenwald, Germany	69·6	26·3	37·2	47·3	25·8	2,867	92·3
Potsdam, Germany	66·1	24·3	34·8	44·7	25·0	2,487	80·3
Allenstein (East Prussia) now Poland	53·9	23·3	34·2	43·7	26·3	2,577	83·3
Riga, Latvia	78·5	22·0	32·8	42·0	23·0	2,217	71·7
Flak, Norway	72·1	21·0	30·8	40·3	24·5	1,997	64·3
Valkjarvi, Russia	67·3	20·3	29·7	39·3	23·2	1,680	54·3
S.E.		0·49	0·83	0·90	0·64	118·3	3·88
L.S.D.5%		1·6	2·8	3·0	2.15	396	12·98
L.S.D.1%		2·4	4·1	4·5	3·2	585	19·21

Notes. (1) 'Top' height and 'Top' girth are obtained from the 100 trees of largest girth per acre.

(2) * The Trentino plots were only 25% stocked at first.

and Cawdor were the tallest, but without any significant difference among them on any occasion. Similarly, Lenti, Darnaway and Loch Maree formed the next group of three on each occasion. In volume production, only the two best provenances, Sopron and Thetford, were significantly superior (at the five per cent level) to the worst, Trentino, which had poor early survival. The two Scottish provenances from the dry zone, Cawdor and Darnaway, have been more productive than Glen Moriston and Glen Garry of the wet zone; but not significantly more productive than Loch Maree. In view of its high early survival, the productivity of Glen Moriston is poor, whereas Trentino, despite heavy early losses, has now produced almost as much volume.

The 1933 plots contain provenances of greater geographical contrast. Only in the survival rates are the Baltic origins as good as the more southerly German Plain plots. In all the height, girth and volume figures obtained, the Baltic and Scandinavian origins are inferior to the five provenances from the German Plain, although the Polish origin (Allenstein) is in some cases intermediate between these groups.

From the adjusted figures in Table 37, combining the two different years of planting, the superior vigour on this site of the provenances from the 'German

Table 38

COMPARISON OF ALL PROVENANCES ADJUSTED TO 32 YEARS OF AGE

Provenance	Region	Total Volume (Hoppus Ft.)	Top Height (Ft.)	
Trottenwald, Germany	German Plain	2,959	48·8	Some heavily branched; mostly moderate.
Wangenbourg, France	German Plain (East France)	2,942	48·5	Mostly of good shape.
Hanau, Germany	Vosges	2,873	48·5	Some heavily branched, some very good.
Allenstein (East Prussia), Poland	German Plain	2,660	45·1	Mostly heavily branched; some good.
Sopron, Hungary	Hungary	2,627	45·3	Some rough trees, but some good.
Potsdam, Germany	German Plain	2,567	46·2	Some rough trees, many good.
Thetford, England	(planted)	2,500	45·0	Moderately good stems.
Riga, Latvia	E. Baltic	2,299	43·3	Very good form.
Cawdor, Scotland	Scotland (dry)	2,267	45·0	Very good form.
Darnaway, Scotland	Scotland (dry)	2,187	42·3	Moderately fine branches.
Loch Maree, Scotland	Scotland (wet)	2,093	40·7	Fine branching, some good stems.
Flak, Norway	Norway	2,061	41·6	Good straight trees.
Lenti, Hungary	Hungary	1,883	42·7	Very rough trees.
Glen Garry, Scotland	Scotland (wet)	1,843	39·7	Small, dense and shapely.
Valkjarvi, Russia	N. Baltic	1,734	40·6	Small, but good shape.
Glen Moriston, Scotland	Scotland (wet)	1,700	38·3	Mixed, mostly very poor.
Trentino, Italy	South East Alps	1,697	43·0	Some good stems; poor bushy crowns.

Plain' (i.e. between the Vosges and Poland) is well illustrated. There is little between the Riga and the better Scottish provenances; the slower Scottish lots and Scandinavians bring up the rear. The 'Thetford' pine seems closer akin to the German lowland provenances than to the Scottish lots.

Discussion

The eight experiments described above leave many gaps in the coverage of provenances, and if they had all been properly designed, they would have provided much more reliable information. However, when the results from all experiments are put together a reasonably adequate picture emerges. It is clear that in Scotland the British provenances were generally superior to those from the Continent, while at Thetford, in a much more Continental climate, the local provenance and those from the N. German plain were the best. Important differences occurred between the Scottish lots, for example, the Darnaway provenance (represented by eight collections) was generally outstanding. Achnashellach was another good seed source. There was no clear-cut distinction between the provenances derived from the native Caledonian pine and those from plantations of unknown ancestry. The seed size of most of these provenances is unknown, though what data there are suggest that those with large seeds have done better than those with small seeds. Since the old Caledonian pine tend to have smaller seeds than more favourably placed plantations, this may have affected their performance adversely. One of the English seed lots (of unknown original provenance) grew well at Thetford, while the other was tallest in both the Scottish experiments in which it was represented.

The experiments are situated at one moderately high rainfall area (Inchnacardoch 48 ins.) and at several low rainfall sites (Teindland 30 ins., Findon 30 ins., Roseisle 25 ins., Thetford 24 ins.). There was no clear indication that provenances from high rainfall areas have grown better at Inchnacardoch than at the dry sites, or vice versa.

The foreign provenances showed great variation, from complete failure (e.g. the north Finland lots) to good growth and survival of those from the Rhine valley (e.g. Haguenau) and from the North German Plain (e.g. Hesse).

The southern Finland lots grew slowly, but with above average stem form and have attracted the favourable attention of visiting timber merchants. Swedish provenances showed the same variation between the fair growth of southern origins to very poor growth of Lapland ones. The Norwegian provenances had many failures and the survivors grew badly, whether they came from east or west. There was considerable variation in the provenances from Latvia, and the authenticity of some is in doubt. The ones thought to be genuine resembled those from southern Finland in growth and appearance. German provenances did best at Thetford and Roseisle and were much poorer at Inchnacardoch. The two Hungarian seed lots were very poor there, but Sopron grew fast (though rather coarsely) at Thetford. French provenances were represented by the Vosges, Haguenau and Auvergne, with the first two considerably better than the latter. Spanish and Russian provenances had very high failures and the survivors were generally poor in form. They exemplify the general conclusion that provenances of Scots pine from high elevations or high latitudes will not make satisfactory growth in Britain.

The tables showing height growth at different ages do not reveal much change in rank with increasing age, except in cases where the original plant

Table 39

List of Provenances and the Experiments in which they Occur

I.N.	Provenance or Origin	Lat. °N	Long.	Elevation feet	Notes	Teindland 32P28	Inchnacardoch 58P28	Findon 1P29	Inchnacardoch 84P29/31	Inchnacardoch 92P31/35	Roseisle 2P30/31	Roseisle 3P35	Thetford 18P32/33
SCOTLAND													
25/502	Beaufort Estate, Sawmill Wood, Inverness-shire.	57°27′	4°29′W	100	Reputed Caledonian?	*			*				
25/503	Pitgaveny Estate, Morayshire.	57°40′	3°17′W	0–50	Large seed (1000 seeds = 6·7 g.)	*			*				
25/504	Loch Fyne, Argyllshire.	56°	5½°W	probably near sea level				*	*				
25/505	Strath Conon, Ross-shire.	57½°	4¾°W	100–500?				*	*				
26/501	Darnaway Estate, Morayshire.	57½°	3¾°W	100–500 approx.				*	*				
26/502	Innes Estate, Morayshire.	57°40′	3°13′W	0–100				*	*				
29/506	Balmacewan, Kincardineshire.	56°47′	2°33′W	100	One tree over 150 yrs. old.					*			
29/531	Glengarry, Inverness-shire.	57°4′	5°W	300?	Natural wood (=32/510?)					*			*
29/532	Inchnacardoch, Blar an Righ, Inverness-shire.	57°8′	4°41′W	100	From 2 trees—natural?					*			
29/534	Glen Mallie, Loch Arkaig, Inverness-shire.	56°55′	5°5′W	300	Natural wood					*			
29/535	Loch Tulla, Argyllshire.	56°33′	4°48′W	600	Probably from Caledonian					*			
29/544	Achnashellach, Sanctuary and Glen Uig, Ross-shire.	57°29′	5°14′W	600	Natural woods					*			
29/545	Coulin Estate, Ross-shire.	57°32′	5°18′W	300–500	Old natural trees					*			
29/546	Shieldaig, Loch Dughaile, Ross-shire.	57°30′	5°38′W	100	Young natural wood					*			
29/547	Loch Maree, Ross-shire.	57°38′	5°21′W	30+	Old natural wood	*			*	*	*		*
29/548	Rhidorroch, Ross-shire.	57¾°	5°W	300	Old natural trees					*			
29/549	Abernethy, Strathspey Estate, Inverness-shire.	57°15′	3°40′W	700	Old natural trees				*	*	*		
29/550	Glen Tanar Estate, Aboyne, Aberdeenshire.	57°2′	2°52′W	600+	Old natural trees					*			
29/551	Glen More, Inverness-shire.	57°10′	3°42′W	1100+	Natural trees					*			
29/552	Ballochbuie, Balmoral Estate, Aberdeenshire.	56°59′	3°20′W	1000–1300	Old natural trees					*			

29/553	Glen Moriston, Inverness-shire.	57°10′	4°47′W	500–700	Old natural trees					•			
29/554	Glen Moriston, Inverness-shire.	57°10′	4°47′W	500–700	Old natural trees				•	•	•		•
29/556	The Bin, Aberdeenshire.	57°28′	2°50′W	500+						•			
29/557	Altyre Estate, Morayshire.	57°35′	3°35′W	100–300	Caledonian progeny?					•			
29/559	Darnaway Estate, Morayshire.	57½°	3½°W	100–500	Trees 70 yrs. old				•	•	•		•
29/560	Darnaway Estate, Morayshire.	57½°	3½°	100–500	Trees 18 yrs. old				•	•	•		
30/539	Abernethy, Strathspey Estate, Inverness-shire.	57°15′	3°40′W	700	Rounded cones					•			
30/547	Darnaway Estate, Morayshire (Black Loch?)	57½°	3½°W	125	Trees 160 yrs. old					•			
30/554	Darnaway Estate, Morayshire	57½°	3½°W	100–500	Not differentiated from 30/555					•			
30/555	Darnaway Estate, Morayshire.	57½°	3½°W	100–500						•			
30/556	Haddo Estate, Aberdeenshire.	57°24′	2°13′W	200	From old trees of good type					•			
31/512	Darnaway Estate, Morayshire.	57½°	3½°W	100–500	Trees 90 yrs. old							•	
31/1031	Cawdor Estate (nr. Castle), Nairnshire.	57°31′	3°56′W	200	Trees 150 yrs. old					•			•
32/508	Black Wood of Rannoch, Perthshire.	56°40′	4°20′W	700						•		•	
32/509	Darnaway Estate, Morayshire.	57°35′	3°42′W	100–200						•			
32/510	Glengarry, Hospital Wood, Inverness-shire.	57°4′	4°48′W	200–400						•		•	
32/511	Glen Mallie, Inverness-shire.	57°	5°W	?	Perhaps=29/534					•		•	
32/512	Inchnacardoch, Blar an Righ, Inverness-shire.	57°8′	4°41′W	100	Probably=29/532					•			
32/515	Strathoykell, Sutherland.	57°58′	4°37′W	200–500	Reputed natural—Poor trees					•		•	
32/535	Altonside, Morayshire.	57°36′	3°11′W	300								•	
32/538	Glenmoriston, Inverness-shire.	57°10′	4°47′W	500–700	Probably=29/553					•			
32/539	Achnashellach, Ross-shire.	57½°	5½°W	200+						•			
33/509	Achnashellach, Glen Uig, Ross-shire.	57°29′	5°14′W	600	Natural wood					•			
33/517	Altyre Estate, Morayshire.	57°35′	3°35′W	100–300						•			
ENGLAND													
26/17	East England Conservancy (Origin only)	52½°	1°E	50–200	Probably Norfolk and Suffolk			•	•				
29/40	Eastern England, local Thetford collection (Origin only)	52°30′	0°30′E	50–200	Original provenance unknown								•
FINLAND and WEST RUSSIA													
25/27	Vyborg, West Russia.	61°	29°E	160–330		•	•						
25/69	Kittila (var. *lapponica*).	67½°	25°E	650	20 trees, 150 yrs. old	•	•						
26/F1	Eveo, Lammi parish.	61°	24½°E	300	Natural wood			•	•				
26/F3	Raivola.	60¼°	29½°E	150	Natural stand, 45 yrs. old			•	•				
26/F6	Sodankylä.	67½°	27½°E	625	Trees 160 yrs. old			•	•	•			

Table 39—*continued*

LIST OF PROVENANCES AND THE EXPERIMENTS IN WHICH THEY OCCUR

I.N.	Provenance or Origin	Lat. °N	Long.	Elevation feet	Notes	Teind-land 32P28	Inchna-cardoch 58P28	Findon 1P29	Inchna-cardoch 84P29/31	Inchna-cardoch 92P31/35	Rose-isle 2P30/31	Rose-isle 3P35	Thet-ford 18P32/33
26/F7	Pieksamäki.	62½°	27°E	400	Trees 80yrs. old			*	*	*			
26/F8	Ahtäri	62½°	24½°E	475	Natural stand	*		*	*	*			
28/52	Valkjärvi, Vyborg, West Russia.	60½°	29°E	?						*			
31/1041	Valkjärvi, Vyborg. West Russia.	60½°	29°E	?	Trees 50–70 yrs. old								*
SWEDEN													
25/68	Alvsby (var. *lapponica*).	65°45′	21°E						*				
27/502	— (var. *lapponica*)	—	—		Possibly=25/68					*			
28/19	Västeråas, Vastmanland.	59½°	16½°E	nr. sea level						*			
30/525	Dalecarlia (=Kopparberg province)	60–62°	13–16°E	600–650						*			
32/540	Västeråas	59½°	16½°E	nr. sea level	Probably=28/19					*			
NORWAY													
26/503	'West Norway'	—	—	—	Sent by Waldemar Opsahl				*	*	*		
30/549	Saevraasvaag, Hordaland, West coast	60°44′	5°20′E	below 150	'One of the best stands of typical coastal pine'—Robak.					*			
31/1037	Flak, Lillesand, Aust Agder.	58°15′	8°23′E	?	By Flak lake								*
32/530	Hedmark Province, East Norway.	60–63°	10–13°E	—						*		*	
LATVIA													
25/67	Riga (var. *rigensis?*)	57°	24°E	—	Doubtful if this is *rigensis*	*	*		*				
26/54	Selburg (var. *rigensis*)	57°	24°E	400	Latvian Min. of Agrl.			*	*				
28/18	— (var. *rigensis*)	57°	24°E	—	Ex-Latvian Forestry Dept. Bought as plants, hence could be same seed as 25/67.	*				*			
31/1033	Riga.	57°	24°E	?	From trees 100 yrs. old								*

GERMANY and POLAND													
31/1038	Potsdam, Rudersdorf, Brandenburg	52°31′	13°49′E	150–300									
31/1039	Trottenwald, Kassel, Hesse.	51°	8°E	?	'Mittelgebirge', c. Medium elevation								*
31/1040	Allenstein, East Prussia = Olsz Tyn, Poland.	53°47′	20°28′E	300–500						*			*
32/518	(East Prussia) now Poland.	—	—	—	Perhaps = 32/1019					*		*	
32/1019	(East Prussia) now Poland.	—	—	—								*	
32/524	Hanau, Hesse.	50°8′	9°0′E	300						*		*	
HUNGARY													
30/56	Lenti.	46°38′	16°32′E	600–800						*			*
30/57	Sopron.	47°40′	16°30′E	1150–1480						*			*
BELGIUM													
31/1012	Herselt, Campine.	51°3′	4°53′E	100						*			
FRANCE													
25/25	Haguenau, Bas-Rhin (var. *haguenensis*).	48¾°	7¾°E	—		*	*		*				
29/505	Forêt de Boisgrand, Puy de Dome, Auvergne.	45°30′	3°34′E	3200	'Fine Auvergne type of pine'					*			
31/1035	Wangenbourg, Bas Rhin, Vosges.	49°	7°E	1450									*
31/1036	Foret de Hanau, Dept. of Moselle, Sarreguemines. Northern Vosges.	49°	7°32′E	1100	'forme de moyenne montagne, race noble de Hanau.'								*
32/517	Haguenau, Bas-Rhin.	48¾°	7¾°E	450–600								*	
32/520	Auvergne	—	—	—	Probably same as 29/505					*			
ITALY													
30/64	Trentino.	46°	11°E	?	Probably fairly high elevation								*
SPAIN													
26/9	Sierra Nevada (var. *nevadensis*).	37°	3°W	6500	North aspect			*	*				
28/31	— (var. *nevadensis*).	—	—	—	Probably = 26/9					*			
SOUTH EAST RUSSIA													
25/70	Ural Mountains (var. *uralensis*).	—	—	—	Supplied by Russian Government			*	*				
26/4	Borzhom, Caucasus Mts., Georgia. (var. *hamata*).	42°	—	3500	Supplied by Russian Government.			*					
27/501	— (var. *hamata*).	—	—	—	Probably—26/4					*			

size or age differed markedly. As it is sometimes necessary to make policy decisions about seed purchase on the early results of provenance experiments, this stability is reassuring. As the experiments mature, only the best individuals will remain in the inferior provenances, so that differences between provenances may be expected to diminish.

Summary

Results are given from eight provenance experiments with Scots pine aged from 24 to 35 years, and containing 90 seed lots. Experimental design was often inferior, thus limiting statistical treatment of the data. Nevertheless, overall conclusions confirm the superiority of home-collected seed lots in Scotland as far as height growth is concerned, and certain sources, e.g. Darnaway Estate, gave notably fast-growing progeny. At the only English site (East Anglia), French and German origins were superior to Scottish lots. Stem form was best in the Fenno-Scandinavian lots from the 61°–62°N parallels and particularly bad in some South European origins. In Scotland, volume production was usually higher in British provenances than in foreign ones, partly because the latter frequently had poorer survival, even in provenances with good height growth. In England, both survival and volume production of these foreign lots was as good as or better than Scottish origins. Provenances from extreme latitudes, both northerly or southerly, or from high elevations, either failed or grew poorly.

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FURTHER TRIALS OF CHEMICALS FOR DE-BARKING HARDWOOD PULPWOOD

By R. M. G. SEMPLE

Introduction

Experiments in the use of chemicals to remove bark from the standing tree, or to facilitate its removal after felling, have been carried out over the last ten years or so. Latterly the work has been aimed specifically at the hardwood pulpwood market, which has assumed importance since the establishment of a mill at Sudbrook, near Chepstow, in Monmouthshire, by the Sudbrook Pulp Mill Ltd., of the Wiggins Teape Group.

There have been three main phases in experimental activity.

(1). **Trials with Sodium Arsenite.** A full review is given by G. D. Holmes, 1955, in his paper: Experiments in the poisoning of standing trees to facilitate bark removal. *Rep. For. Res., For. Comm.* 1955, pp. 119–26. This was primarily the trial of a new technique on a wide range of species, both hardwood and conifer. Costing was not carried out in any detail and the production of hardwood pulpwood was not a major objective. Promising results were achieved, but because of its known high toxicity to humans as well as plant life, it was not considered desirable to pursue further trials of sodium arsenite.

(2) **Trials with a Wide Range of Chemicals** (see G. D. Holmes, 1961. Chemical de-barking of hardwood pulpwood. *Rep. For. Res., For. Comm.*, 1961. pp. 184–196). From these trials diquat emerged as the most likely material both as regards effectiveness and low toxicity. These trials were confined mainly to oak in the pole-stage, and no general conclusions could be drawn which would be applicable to other species, or larger trees; nor did they give sufficiently accurate information on the costing or economics of the operation.

(3) Two experiments, with diquat as the principal chemical, designed to supply the information not forthcoming from the earlier work, i.e. the effects on a range of species, and on older trees, along with detailed costings which would enable the economics of the technique to be assessed. These experiments are summarised below; results are discussed in fair detail but no attempt is made in this paper to describe the minutiae of the experimental methods or the assessment techniques.

Experimental Work

(a). **Chepstow Forest, Experiment 1. Pole-stage, Mixed Hardwoods for Pulpwood.** Diquat at ½ lb. active ingredient per gallon was applied in two forms to the exposed sapwood immediately after the removal of a 'sleeve' of bark near the base of the tree. Application took place in the period of active sap-rise (latter half of May). A variety of barking tools was used to remove the 'sleeve', and detailed timings and costings were made of the operation of applying the chemical. The total area was ten acres, the principal species being alder, birch, cherry (*Prunus avium*) and wych elm (*Ulmus glabra*).

Results. Both forms of diquat gave excellent kill and bark-loosening in oak and willow. With *all* other species results were unsatisfactory, ranging from wholly ineffective to distinctly patchy—even when a complete kill was achieved. Some species were in fact *less* easy to peel than had they been left untreated; ash in particular, was rendered so difficult to peel even by the machine peeler at the Sudbrook Pulp Mill that it was no longer acceptable as unpeeled pulpwood. These results throw very serious doubt on the practical value of the method. For field application a simple treatment giving uniform results with all species and a very high level of success is the only one that can be considered.

Costs. It was not possible to run this experiment to its planned conclusion (which included costings at the conversion stage, and out-turn at the mill in proportions of peeled and unpeeled material). The volume of oak and willow was so low—about one ton of oak on ten acres—that realistic working was out of the question; the other species were too hard to peel within the declared limits of the original experiment plan. It was decided to cut losses and close the experiment after the first stage had been completed; clearly the method was not a practical one for general use in the field. Nevertheless some useful costings were obtained, though interpretation was somewhat difficult; they do, however, give an idea of the sort of costs which would be involved should a really effective chemical be discovered, whose method of application is similar—as seems likely—to diquat and which gives the same results on all species as the latter did on oak.

The original experiment plan estimated production at 10 tons per acre; this was obviously low and the forester conducting the work based his costings on a figure of some three times this amount. Yield per acre obviously makes an enormous difference to unit costs per hoppus foot. The following figures *assume* 25 tons per acre at 30 hoppus feet per ton, when weighed green or unseasoned at the pulp-mill weighbridge a few miles from the forest. (1 hoppus foot=1·273 true cubic feet).

N.B. The costs quoted below are comparative ones, and relate to the years 1961–1962.

Treatment Cost	
Labour (direct) £7 per acre	2·25d per hoppus foot
(overheads 40%)	0·9d ,, ,, ,,
Materials £4. 7s. 0d. per acre	1·4d ,, ,, ,,
Total	4·55d ,, ,, ,,

Peeling Cost (estimate from the few samples which were fit to peel).	
Labour (direct)	3·0d per hoppus foot
(overheads 40%)	1·2d ,, ,, ,,
Total	4·2d ,, ,, ,,

On these assumptions the combined cost is 8·75d. per hoppus foot.

For comparison, the "peeling bonus", paid by the pulpmill as discussed on page 198, is equivalent to 16d. per hoppus foot.

(b) Dean Forest, Experiment 85. Chemical Peeling of Slabwood and Cordwood. The primary objects of this experiment were to test the feasibility of barking of oak slabwood following felling of treated trees and conversion at the sawmill; and to examine the ease of bark removal from cordwood prepared from limbs after felling. Diquat and paraquat were used, at two different rates of application, both frill and band girdling being compared. In addition 2, 4, 5-T was tested at a single rate of application, with comparisons between frill girdling and basal bark spraying.

A small stand of oak was selected, of minimum breast height/quarter girth of 8 inch, and treatments were applied in June 1961. The trees were felled in the winter and spring of 1962. Careful assessments and observations were made on the following, and costings kept where appropriate:—ease of peeling of the logs; time and ease of peeling of the cordwood, with costings; volumes and weights of cordwood produced per tree, and the volume of each log; and the degree of removal of bark from the slabwood during handling and conversion.

The following conclusions were reached:—

(i) Whilst almost all treatments killed the trees satisfactorily, none was 100% effective in loosening the bark. Diquat, at the higher rate, applied to a band girdle, gave most promise, but there was little real variation between treatments.

(ii) Loosening of bark on cordwood was erratic, and whilst the more successful treatments showed some saving in peeling time both over the controls and over the less successful ones, this was not large. Peeling costs (including 40% overheads) were 11·5d per hoppus foot—averaged for *all* treatments *and* controls. For the more successful diquat treatments the average cost on the same basis only came down to 10·5d per hoppus foot. To these have to be added the costs of application; apportionment of these to the cordwood is difficult, and though they are not high, the combined figure is clearly a good deal higher than that estimated for the pole-stage material in the previous experiment.

(iii) All logs were followed up to the stage of conversion at the sawmill. In this experiment practically no bark shedding occurred and the slabwood would have been valueless as peeled pulpwood. Abrasion due to extraction, handling and conversion could be assessed as 'normal'. There was no apparent difference between treatments or dates of felling.

It was considered that these somewhat disappointing results might be due to the late date of application of the herbicides. An extension of the experiment was, therefore, carried out in 1962 in the same stand as the original on trees of a similar range of sizes. In this, diquat was applied at a fairly high rate to band girdles on a series of dates ranging from mid-April to mid-July. All trees were felled together in the late spring of 1962; interim assessments had been made in the same way as before. The criteria applied in the final assessment were identical with the original experiment, but in some respects more detail was obtained, whilst in others less relevant items received less attention.

This extension trial was on a fairly small scale and it would be unwise to base too definite conclusions upon it. There was, however, a strong indication that the most successful treatments were carried out in a quite short and strictly defined period—from about the 16th of May to the 13th of June. Even within this period there were indications that individual trees varied considerably in their response to treatment according to the date of application; but both before and after these dates results were, almost without exception, poor—at least as unsatisfactory as in the original experiment. In the greater part of the trees treated in the 'optimum' period, however, bark shedding was greatly improved, peeling time for cordwood reduced by about 45%, and the slabwood was virtually free of bark—frequently before conversion. Unfortunately the dates quoted will vary with the season and are unlikely to be predictable. The variation in the response of individual trees would seem to be correlated with the state of sap-flow. It should be possible to judge the best time of application from external observation—bud swelling is a good indication—but this would involve repeated careful inspections and frequent treatment of individual trees over a period of about a month. This is obviously neither a practical nor an economic proposition; yet something very near 100% success must be assured if any really worthwhile result is to be achieved.

Discussion

The principal objects of this experimental work were to increase the yield of hardwood pulpwood by making available material which cannot be dealt with by the type of de-barking machinery at present in use. The main sources of the increased yield would be crooked roundwood and slabwood. These would have to be delivered at the mill on terms not less favourable than those for unbarked pulpwood. Hence any additional treatment to remove bark should not cost more than the present 'peeling bonus' of 40s. per ton. (The "peeling bonus" is an addition to the basic "unpeeled" price; it is paid by the pulp-mill firm for material received already peeled). In practice it should cost considerably less.

Hardwood pulpwood is a commodity which, at best, earns a very small profit and uses a considerable amount of labour and machinery in the process. The profit margins indicated by these experiments do not appear large enough to justify an additional labour-consuming stage in the process of preparing pulpwood. It is doubtful, in fact, if they are even large enough to cover such contingencies as an occasional failure due to faulty technique, exceptional weather and the like. It must be remembered that these experiments were carried out under good site conditions, using staff well practised in the work and supervisors with special and considerable experience in the use of herbicides. Overheads were calculated at a low rate and could well rise above this figure. As no success has been achieved so far with any major species except oak, any really substantial increase in output seems unlikely.

For the field forester (and, even more, for the private owner) any method of bark removal must not only be cheap; it must also be simple, free from complications of timing and technique, and preferably from long delays between first and final stages. Most important of all it must be certain in its results and practically universal in its application to a wide range of species and conditions. Partial effectiveness is much more costly than no treatment at all.

Conclusions

(1) The experiments so far have shown some promise, but only with oak; even with this species there are serious reservations. We are still a long way from developing a method which is simple, certain and applicable to a wide

range of species; nor are we near the stage where the method promises a profit margin sufficient to justify the additional work it will involve.

(2) Further research on similar lines does not at the moment appear very promising. The appearance of a new substance of wider effectiveness would of course be encouraging, and changes in the price structure for hardwood pulpwood might allow greater margins in which to work. However, at present it hardly seems that chemical methods of debarking are likely to make any very considerable contribution.

(3) At present it appears that the most rewarding line of research in this field remains with the development of debarking machinery at the mill.

MANAGEMENT AND OPERATIONAL RESEARCH: A LINEAR PROGRAMMING STUDY

By P. A. WARDLE

Introduction

(1) A great deal of the difficulty of the job of management stems from the complexity of the problem with which the manager is confronted. Even if information about the quantities he has to control is available, it is frequently so intricate in detail and in the inter-relationships involved as to make it impossible to use in its complexity. His skill has therefore consisted in making the most promising approximation. He has been helped by economists who have directed his attention to the quantities most correctly representing his success and by work study and industrial engineers who have evaluated the physical possibilities. The intricacy of the problem remains.

(2) As a result of the pioneer work of mathematicians and economists in the thirties and the urgency of organisational problems in the Second World War, both in the development and production of equipment and the organisation of the operations themselves, mathematical systems have been developed which allow such problems to be represented in their complexity. The development of computers has made their solution a practical proposition. Indeed these developments have allowed the growth to the status of a discipline in its own right of Operational Research—the application of mathematical techniques to problems of organisation with the objective of optimizing the performance of the system.

(3) In this note the technique known as linear programming is applied to a problem of allocation which involves interaction between particular choices. Many management problems are further complicated by being dynamic—that is involving interaction through time as well as between variables—or they involve uncertainty. Such problems also lend themselves to numerical analysis. Through the description of an example it is hoped to demonstrate that the information available to management is both improved and extended by such analysis.

The Problem of Interaction

(4) Before going on to the main problem it is desirable to be quite clear about the difficulty we are attempting to overcome in the allocation problem.

(5) If the situation were such that one could buy discrete units of resources of exactly the right volume to carry through the particular project and the only restriction on the projects to be done was the amount of money available to buy resources, then by assessing the profitability of all possible projects and picking projects starting from the most profitable and working downwards until the available money is used up, the best collection of projects would be obtained. In practice the choices confronting the manager are not so straightforward. In

addition to the amount of money available being limited, the raw materials at his disposal are restricted and a large part of the cost of operation may already be committed in capital equipment. Though the financial objective of the enterprise may be paramount, pursuit of this objective may be restricted by other requirements imposed from outside. In these circumstances, although the relative profitability of individual projects can be evaluated, these make varying demands on the raw material and existing capital equipment and fulfil to varying extents the other requirements of the enterprise. The manager has not only to decide between straightforward alternatives but to pick the best from a collection of alternatives, each of which interacts with the remainder.

(6) The following example illustrates in very simple terms the nature of the problem. Suppose a forester has 100 acres of forest with over-mature hardwood timber worth £200 per acre if felled in the coming period; in the following table the operations open to him are listed with their cost in immediate resources and the net return which results per acre. The net returns consist of the value of timber felled plus the net value expected from the replacement crop, all discounted to the present.

Table 40

COST AND NET RETURN OF ALTERNATIVES

Operation	Cost £ per acre	Net Return £ per acre
(1) Fell hardwood and plant pine	50	250
(2) Fell hardwood and regenerate	10	220
(3) Retain hardwood (postponing action to a later period)	0	180

The objective of the enterprise is to get the largest total net return. Pursuit of this objective is subject to the constraint that only £2,500 is available to meet costs whatever programme is chosen. Table 41 gives examples of possible alternative courses open to the enterprise and the total net return resulting.

The obvious course of action is to do as much as possible of the most profitable alternative, fell hardwood and plant pine. In the absence of any budgetary constraint this would lead to the most profitable result. Because of the restricted budget it is in fact possible to treat only half the area in this way and one is forced to adopt the least profitable alternative, to retain hardwood, on the remainder of the area. One can do better by adopting the second alternative, fell hardwood and regenerate. The best course of action is to adopt a combination of treatments so that pine is planted to an extent that leaves just sufficient funds to allow the regeneration of the remainder. In this example involving only three possible operations, one area and one restriction, the problem of deciding the best combination is easily handled. It is immediately apparent, however, that if a number of areas were involved each with a set of possible operations making varying demands on resources, and of varying value, and other restrictions were imposed on pursuit of the objective beside the budget, then the problem may no longer be easily solved by trial and error as shown in Table 41. Determination of the optimum felling programme for the New Forest involves this sort of complexity. The analysis described below was part of the analysis which formed the basis on which the felling programme in the Working plan was decided.

Table 41

COURSES OF ACTION

	Operation		Result Total Net Return £
(1)	*Fell hardwood*		
	and plant pine on 50 acres		12,500
	retain hardwood on remaining 50 acres		9,000
	(half the area is planted, all resources used up)		
		TOTAL	21,500
(2)	*Fell hardwood*		
	and regenerate hardwood on 100 acres ..	TOTAL	22,000
	(whole area restocked, £1,500 left over)		
(3)	*Retain hardwood*	TOTAL	18,000
	(no planting done, £2,500 left over)		
(4)	*Best combination*		
	Fell hardwood over whole 100 acres and plant 37½ acres to pine		9,375
	regenerate 62½ acres to hardwood		13,750
	(whole area restocked and resources used up)		
		TOTAL	23,125

Felling Programme for the New Forest

(7) The prime objective in the management of the New Forest is a financial one, in keeping with the policy of the Forestry Commission. Pursuit of the financial objective is subject to certain well-known restrictions which derive from the legal status of the New Forest and from its importance as a holiday area. Over a large part of its area—the Open Forest—commercial forestry is not permitted, and over a large part of the woodlands—the Ancient and Ornamental woodlands—forestry is restricted to the maintenance of the woods as a visual amenity. Areas where commercial forestry is not permitted have been excluded from the problem. Areas where the costs of postponing action are comparatively trivial, e.g. larch crops which might ideally be treated in the period, but where postponement will only cost a few pounds, have also been excluded. In fact, the problem whose solution it was decided would be of most immediate value in planning the management of the New Forest was that of choosing the optimum felling programme in hardwood, conifer, and mixed high forest within the statutory inclosures, the felling programme to be for the next 10-year period. The data about crops and site types was obtained from the Working Plan survey, while the restrictions on management were decided by the local staff to conform with amenity requirements and the capacity of the labour force. The criterion for financial success was taken

to be maximum net discounted revenue, and in formulating the problem the addition to cost and revenues expected to result from alternative courses of action were discounted to the present.

Definitions

(8) The problem can be formulated if the following are defined:

(a) The objective.

(b) The restrictions or constraints on the pursuit of the objective.

(c) The various discrete alternatives open to management—these can usefully be called 'activities'.

(d) The relationship between each activity and particular constraint and,

(e) the value associated with a unit of each activity.

Taking these in turn:—

(a) The objective is taken to be to maximise net discounted revenue, subject to

(b) the constraints—these in physical terms are:—

(i) The volume felled in the period from conifer and mixed high forest not to exceed 4·16 million hoppus feet.

(ii) Volume felled in the period from old hardwood not to exceed 2·44 million hoppus feet.

(iii) Area treated (as distinct from treatment being postponed) not to exceed 5,000 acres.

(iv) The conifer area resulting from the chosen programme not to exceed 3,845 acres (this is to ensure that the area of conifers does not exceed 50% of the area of the whole forest).

(v) 500 acres to be planted with hardwood/conifer mixtures.

The total area considered in this problem is some 8,500 acres out of the total Working Plan area of some 30,000 acres.

(c) *Activities* (see Table 42). There are in the potential felling area a number of crop classes which may be treated in a variety of different ways.

The crop classes are: old hardwood, old conifers, mixed high forest, and bareland. The old hardwoods are further broken down into classes with varying volumes and quality of timber per acre, some with a viable understorey and some without. The alternative treatments are felling, followed by planting either of a conifer or a hardwood/conifer mixture; where an understorey exists felling may be followed by retention of the understorey or enrichment as well as the planting alternative. Any treatment may be postponed to the next period. The treatment of a particular crop class in a particular way constitutes an 'activity.'

(d) *Activities and Constraints* (see (c) above and Table 42). The relationship between the activity and a particular constraint depends on the nature of the constraint. An example illustrates the relationship: felling and planting with conifer one acre of conifer high forest yields 4,000 hoppus feet, thus the relationship to the conifer volume constraint (i) is 4,000. It yields no broadleaved volume so the relationship to the broadleaved volume constraint (ii) is 0. One acre of felling and planting is one acre treated, so the relationship to the treatment constraint (iii) is 1. Similarly for the conifer area constraint (iv) the relationship is 1. Felling and planting one acre of conifer high forest means one acre of that class is treated but none of any other class, so that the relationship to the constraint on the area treated (v) in the conifer high forest class is 1, but the relationship to constraints on area treated in all other classes is 0.

(e) *Value*. The value of each activity is the net discounted revenue associated with one acre of that activity. In calculating the NDR* the value of the existing crop and the NDR of the replacement crop are taken into account: felling one acre of conifer high forest yields on average £400, the net discounted revenue expected from the conifer replacement crop is £87 so that the net discounted revenue associated with the activity, felling conifer high forest and replanting with conifer, is £487 per acre. The NDR where treatment is postponed is the highest NDR expected to be possible in the next period discounted over ten years. The relative sizes of these values are important in determining the optimum course of action.

Formulation

(9) The problem may now be set up as a linear programming problem which may be represented in the following manner:—

Objective function: maximise $Z = cx$,

Subject to a set of constraints:

$$Ax = b$$
$$x \geqq 0$$

Where Z is the total net discounted revenue

Where x represents the set of activities,

c the value coefficients,

b the constraints and

A the matrix of coefficients relating the activities and the constraints.

The system consists of a set of simultaneous linear equations in which the number of variables exceeds the number of equations. The number of feasible solutions to such a set of equations is large, the system required, however, that that solution is selected which results in maximum net discounted revenue.

(10) The statement of objective and constraints and the detail presented in Table 42 are sufficient to set up the linear programming problem which consists of 18 equations involving about 70 variables, to be solved simultaneously. The process of computation is iterative. First a basic feasible solution is found that is a programme of activities which is both possible and consistent with the constraints; this is then revised by substituting an activity not included in the solution (which, it can be seen, will improve the result), for some activity in the present solution. This revision of the basis requires revision of the problem which involves computation on the values of b and c and the coefficients A in the equations. This process of substitution is repeated until no further improvement in the result is possible—the optimum solution is achieved.

In the example described here, this required 35 steps, and took about 30 minutes on the Sirius computer.

*NDR= Net discounted revenue.

Table 42

CROP TYPES AND THEIR TREATMENT: AREA, VALUE AND VOLUME

Crop Type	Old Hardwoods										Conifer & Mixed		
	Complete understorey	No understorey	Partial understorey	Complete understorey	No understorey	Partial understorey	Complete understorey	No understorey	Partial understorey	Complete understorey	Conifer High Forest	Mixed High Forest	Bareland
	A_1	A_2	A^{u_2}	B_1	B_2	B^{u_2}	C_1	C_2	C^{u_2}	D_1	CHF	MHF	Bareland
Area of crop type (acres)	12	1897	500	197	523	130	39	646	170	345	1598	405	1761
Treatment: Value, £ per acre													
(1) Fell & plant conifer	287	287	287	207	207	207	157	157	157	287	487	337	87
(2) Fell & plant hardwood/conifer mixture.	215	215	215	135	135	135	85	85	85	215	415	265	15
(3) Fell & retain understorey	228	—	—	148	—	—	98	—	—	228	—	—	—
(4) Fell & enrich understorey.	—	—	292	—	—	212	—	—	162	—	—	—	—
(5) Postpone treatment 10 years	204	204	204	148	148	148	112	112	112	204	371	264	61
Volume if felled; hoppus feet per acre	2000	2000	2000	1200	1200	1200	700	700	700	2000	4000	2500	—

Table 43

SUMMARY OF RESULT

		Crop Type	Treatment	Area (acres)
Old hardwoods:	High volume and complete understorey	A_1	Postpone	12
	High volume—no understorey	A_2	Plant hardwood(a)	20
			Postpone	1877
			Total	1897
	High volume—partial understorey	A''	Enrich	500
	Intermediate volume complete understorey	B_1	Postpone	197
	Intermediate volume no understorey	B_2	Postpone	523
	Intermediate volume partial understorey	B''	Enrich	140
	Low volume complete understorey	C_1	Plant hardwood	39
	Low volume no understorey	C_2	Plant conifer	582
			Postpone	64
			Total	646
	Low volume partial understorey	C''_2	Enrich	170
	As A: but younger	D_1	Plant hardwood	345
Conifer and mixed:	Conifer high forest	CHF	Plant conifer	1040
			Postpone	558
			Total	1590
	Mixed high forest	MHF	Postpone	405
Bareland:			Plant conifer	1665
			Plant hardwood	96
			Total	1761
	Total area treated in Decade			4587
	Resulting Net Discounted Revenue			£1,843,000

Note: (a) hardwood = hardwood/conifer mixture.

The Solution

(11) The solution is set out in Table 43. This consists in programmes showing the area of treatments chosen for each crop type which will produce maximum net discounted revenue together with the value of Z, the total NDR expected. This, however, does not exhaust the information available. In addition to the optimum programme, solution of the problem throws up information about the cost and benefit associated with varying the restrictions on management or carrying out different activities from those specified in the solution. In this case the operative constraints, that is those restrictions preventing an improvement in the result, are the following:—(see paragraph 8 (b)).

(a) The requirement that the area of conifers resulting from the programme should not exceed 3,845 acres (iv).
   Relaxation of this constraint would result in an improvement of £25 per acre of additional conifer allowed.

(b) The restriction on the volume of conifer high forest that may be felled (i).
   Relaxation of this constraint would result in an improvement of £29 for an addition of 1,000 hoppus feet in the volume permitted to be felled.

(c) The restriction on volume of old hardwood that may be felled (ii).
   Relaxation here would result in an improvement of £28 per additional 1,0000 hoppus feet permitted to be felled.

(d) The requirement that at least 500 acres be planted to hardwood/conifer mixture (v).
   Relaxation of this constraint would result in an improvement of £47 for each acre removed from the requirement.

(e) The restriction of the area that might be treated (as distinct from being postponed) during the period to 5,000 acres (iii) did not affect the solution, only 4,587 acres were, in fact, treated in the solution.

(12) This information leads one to review the formulation of constraints to ensure that they correctly represent restrictions on the management of the forest. An earlier formulation of the problem, for example, did not include any requirement to plant hardwood/conifer mixtures. The solution resulted in no hardwood planting being included; the local staff, however, believed some hardwood planting to be essential to conform with requirements of visual amenity. The present solution shows that if this requirement can be fulfilled by other means the financial result will be substantially better. Introduction of the constraint in fact led to a reduction of £24,000 in the expected NDR.

(13) The solution presented is not the only one which will result in maximum net discounted revenue. It is clear that where some hardwood planting is to be done, if it is assumed that the net discounted revenue of hardwood planting and that from conifer planting is the same on all areas—as has been done in this problem—then it does not matter on which of the areas to be planted the 500 acres of hardwoods is put. The species planted may therefore be decided on other grounds; such as recognisable site variations not considered in the problem, or local amenity requirements. Other alterations which can be made at zero cost (that is without affecting the value of NDR achieved) involve the interchange of treatments of high volume old hardwoods A_1, A_2 or D_1, which in this formulation prove to be to all intents and purposes the same

Table 44

SUMMARY OF RESULT SELECTING THE MOST PROFITABLE ACTIVITIES FROM TABLE 42 (ACTIVITIES WRITTEN IN ORDER OF SELECTION)

Crop Type	Treatment	NDR £ Per Acre	Volume Million H. Ft.	Area Acres	Total NDR £.000	Remarks
Coniferous and Mixed						
1. CHF	Fell and plant conifer	487	4·16	1040	507	4·16 exhausted conifer volume constraint therefore treatment of remaining conifer and mixed crops must be postponed.
CHF	Postpone treatment	371	—	558	207	
MHF	Postpone treatment	264	—	405	107	
Old Hardwoods						
2. A''_2	Fell and enrich understorey	292	1·00	500	146	
3. A_1	Fell and plant conifer	287	0·02	12	3	
4. A_2	Fell and plant conifer	287	1·42	710	204	2·44 exhausts hardwood volume constraint therefore treatment of remaining hardwood crops must be postponed.
A_3	Postpone treatment	204	—	1187	242	
B	Postpone treatment	148	—	850	126	
C	Postpone treatment	112	—	845	95	
D	Postpone treatment	204	—	345	70	
5. Bareland	Plant conifer	87		1261	109	
	Plant hardwood/conifer mixture	15		500	7	This is required by the conifer hardwood mixture constraint.

Total Area Treated in Decade = 4,023 acres.
Resulting Net Discounted Revenue = £1,823,000.

crop type. One might therefore choose to substitute treatment of A_2 for that of D_1, the younger crop type, on the supposition that the latter is less likely to come to any harm if treatment is postponed. Some other activities can be introduced at low cost, for example, revision of the programme to include some treatment of B_1 medium volume old hardwood and B_2 is done at a cost of £1 per acre, or postponement of treatment of low volume old hardwoods C_1 and C_2 is done at zero cost. One might have expected the inclusion of the retention of hardwood understorey in the solution; this, however, has been completely displaced by the requirement that hardwood/conifer mixtures should be planted and is only introduced to this formulation at rather high cost. In the absence of the hardwood planting constraint, retention of understorey would be selected rather than hardwood/conifer planting.

(14) In the previous paragraphs the value of relaxing constraints and the cost of making particular alterations to the programme have been mentioned. The values and costs given refer to unit changes in the programme and the extent of change to which this value will apply is limited. To illustrate this one may cite the example of the requirement to plant 500 acres of hardwood/conifer mixtures in this problem. Relaxation of this constraint is worth £47·5 per acre, whereas the initial introduction of hardwood planting cost only £46 per acre. Achievement of the benefit indicated for the relaxation of a constraint may depend not on simple substitution of the new activities in the programme but on more general revision of the programme. Thus although the result indicates where a change may be desirable or acceptable, incorporating the change in a new programme may require revision of the problem and a new solution.

Variation of Assumptions

(15) In formulating the problem it was necessary to assume that the crop types represented by their average condition were uniform and that the values associated with each treatment were at least in correct relation to one another, though in fact the crop types are quite variable and there is some uncertainty about the relative values of particular crop types and treatments. A great merit of the analysis is that once the problem has been formulated the solution indicates the quantities in the problem that are critical. If one has doubts about the correctness of particular assumptions or wishes to revise the restrictions, this is no less than part of the exercise, indeed it was this part which one hesitated to carry out in the absence of computer aids when one was confronted by a series of arduous computations every time the implications of a new assumption were to be explored.

Value of the Analysis

(16) The question remains, given the added information and some assurance that the chosen programme is the best, is that best so much better than the programme which would have been chosen without the computation? In Table 44 a programme has been worked out by selecting first the most valuable alternatives and continuing down the list in order of value until one of the restrictions prevented one going any further. The resulting net discounted revenue, £1,823,000 compared with £1,843,000, shows that if the problem is set out as illustrated in this paper, by careful appraisal of the volume and

value ratios, it is possible in this problem to select a programme which approximates the optimum programme closely.

As has been demonstrated however, the result of this analysis is not only an optimum programme of treatments, which in itself may have been difficult to arrive at in the absence of the analysis, but also information about the effect of changes in the programme on the result. In many cases it may be that this 'sensitivity analysis'—the information about the value of change in constraint or introducing new activities—may be the most valuable information resulting. It is this information which provides critical guidance on the direction management should take.

Summary and Conclusions

(1) Many management decisions do not involve clear cut choices between simple alternatives but rather the reconciliation of alternatives which conflict with one another and are variously affected by restrictions on management. The best course of action in these circumstances is not immediately apparent.

(2) A clear specification of the management problem which defines:—

(a) the objective to be pursued.

(b) restrictions on its pursuit.

(c) the discrete alternatives open to management.

(d) the relationship between these alternatives and the restrictions, and

(e) the contribution made by each alternative to the objective; may be sufficient to allow the best solution to be recognised.

(3) For those cases which are too complex to be solved by inspection or simple computation, the technique of linear programming or some other form of numerical analysis, may allow solution.

(4) In addition to the optimum solution to the problem, the use of linear programming gives information about variation of the optimum programme and changes in the restrictions on the programme, which may provide critical guidance on the direction which management should take.

SEED ORCHARDS IN BRITAIN

By R. FAULKNER

Introduction

An outline of the basic breeding programme of the Genetics section of the Forestry Commission Research Branch has been published previously (Matthews 1960, 1962) with a more detailed plan for Scots pine by Matthews & McLean (1957). Successive *Reports on Forest Research*, published annually from 1950 (Forestry Commission, 1950–62), have included details of the selection of seed sources and plus trees and the establishment of seed orchards. A summary of the situation for seed stands up to September 1961 was prepared by Faulkner (1962).

This report presents details of clonal and seedling seed orchards either fully or partially established before March 31st, 1964. Reference is made to both Forestry Commission and privately owned seed orchards. Excellent accounts of and discussions on the concepts design and planning of clonal and seedling seed orchards appear in recent papers by Andersson (1963), Zobel & McElwee (1964) and Johnsson (1964).

Historical

The first recorded tree seed orchard in Britain was planted in 1931 by J. Scrymgeour-Wedderburn, Esq., on his Birkhill estate in Fife, Scotland. This orchard, which still survives, is composed of a mixture of selected plants derived from seed collected from open pollinated 18th century European larch trees growing at Birkhill, and first generation hybrid larch seedlings from Dunkeld, Perthshire. The orchard was established with the object of producing a backcross in which slower growth and better stem form would be introduced by using the European larch as pollinators. Similar orchards were planted at Birkhill in 1934 and 1937 and from 1951 to 1955 nine additional seedling orchards were established using various European and hybrid larch mixtures (see Table 50). Relatively close planting (12 ft. × 12 ft.) and war-time neglect greatly reduced the usefulness of the first orchards for seed production, but yields of seed from some of the younger ones has amounted to sixty pounds per acre in bountiful seed years.

The first British clonal seed orchard was planted in 1952 at Newton Nursery, Morayshire; three and a half years after the establishment of the Forestry Commission Genetics Section. This orchard, which has been described in detail by Mitchell (1959), consists of twelve Japanese and three European larch clones and is designed for the production of hybrid larch (*L. X eurolepis* Henry) seed. The parent clones were grafted on site to a top-cross design using alternate lines of alternative clones with a spacing between grafts of 15 feet × 15 feet. In 1953 small Scots pine and Douglas fir top-cross orchards were grafted on site at Drumtochty, Kincardineshire and a second hybrid larch orchard was established at Mabie, Dumfriesshire.

Polycross designs for clonal seed orchards were introduced in 1953 and used for a small European larch orchard at Drumtochty and a hybrid larch orchard at Grizedale, Lancashire. The Grizedale orchard is probably unique in that it was established in a forest clearing around three of its constituent parent clones which were left standing to act as pollinators. Polycross orchard designs have been used exclusively since 1953 for all out-crossing species. As the name implies polycross orchards contain a balanced mixture of many clones which are arranged in such a way that no clone occurs in neighbouring positions either before or after thinning. It is intended that a mechanical thinning, in which alternate grafts are removed, will be carried out shortly before the crowns of the grafted plants begin to compete with each other.

A fifteen-foot spacing between grafts has been generally adopted for seed orchards of most species, but in some privately owned Scots pine orchards the grafts have been planted at 18 feet or 21 feet in each direction to delay or eliminate the need for thinning in later years. The early larch orchards were also planted at 15 feet spacing but since 1957 a spacing of 15 feet × 7½ feet has been used with the object of increasing the pollen supply during the early stages of development (Mitchell 1959).

Grafting on the seed orchard site was largely abandoned by the Forestry Commission after 1954 when improved indoor grafting facilities became available. The use of glass houses and electrically heated frames greatly increased the yields of successful grafts, which are subsequently planted out to form seed orchards. Indoor grafting is particularly useful when only weak scionwood is available (Lightly and Faulkner 1963). Well developed scionwood from vigorous side shoots can usually be satisfactorily grafted onto established rootstocks grown out-of-doors in special forest nurseries. Limiting the grafting work to a few propagation centres permits mass production methods to be used and makes fuller use of the available skilled grafters. The direct planting of grafts onto seed orchard sites has proved to be a highly successful method of establishing seed orchards of pines, larches and beech but difficulties have been experienced in establishing Douglas fir by this method. Consequently since 1961 there has been a trend towards grafting Douglas fir onto large (3–4 feet tall) rootstocks previously established on the orchard site and taking advantage of any side and overhead shade. This follows the procedure now generally adopted for Douglas fir in Denmark (Naess-Schmidt *et al*) and British Columbia.

Private seed orchards have been established by grafting on site, or, by planting out grafted plants.

Composition and Size of Seed Orchards

The method of selecting phenotypically superior parent trees, or *plus trees* on which all clonal seed orchards have been based, has been described by Matthews (1956) and in detail for European larch by Mitchell (1956) and for Scots pine by Matthews and McLean (1957).

Scots pine orchards owned by the Forestry Commission range from ½–3½ acres in size and contain from ten to thirty clones. Most of the orchards have been based on twenty clones with twenty ramets of each clone planted to a square two-acre polycross design. Privately-owned Scots pine orchards are generally much smaller and seldom containing more than ten clones in a half-acre unit. This is understandable since they are only required to provide small quantities of seed for local use. At present there are no Scots pine seedling seed orchards.

A programme for Lodgepole pine seed orchards was begun in 1961 with a one-acre experimental clonal orchard at Newton. Two additional larger orchards to produce 'cultivars' of *coastal* or *inland* origins were started in 1962 and 1963 and a 4¾-acre orchard composed of clones selected from various plantations of coastal origins growing in Eire was established at Keillour Forest, Perthshire in 1964. Slow progress is expected in the future extension of Lodgepole pine clonal orchards mainly because the acreage of medium aged plantations from which plus trees can be selected is at present quite limited. As an interim measure, upwards of fifty acres of seedling seed orchards will be established in 1965 using seedlings derived from open pollinated superior phenotypes from 'Terrace', 'Prince George' and 'Hazelton' provenances in British Columbia growing in Scotland. The 'Terrace' provenance is intermediate in habit of growth between *coastal* and *inland* types.

With the exception of the first hybrid larch orchard at Newton all Forestry Commission clonal hybrid larch seed orchards contain a balanced mixture of European and Japanese larch clones. The orchards range from half to ten acres in size, the smallest of which were established primarily for experimental purposes. Many orchards planted after 1955 contain up to sixty clones.

Seedling orchards of larch which have been established by the Forestry Commission at Clanna in the Forest of Dean, Gloucestershire and privately in Aberdeen, contain progenies derived from the controlled pollination of plus trees. The Forest of Dean seed orchards are essentially progeny trials planted in such a way that when all useful information on progeny performance has been obtained they can be managed for producing F_2 hybrids and various backcross combinations.

There are eight Douglas fir clonal orchards ranging from half to three acres in size and based on from ten to fifty-three clones. In addition there is one small Douglas fir seedling orchard at Duns, Berwickshire, which is composed of progenies derived from both controlled and wind pollinated plus trees.

Pilot clonal seed orchards of beech, ash, oak and western red cedar are all one acre or less in size. Most have been established for experimental purposes. There are no Sitka or Norway spruce seed orchards at present but preparations are in hand to establish the first Sitka spruce orchard in 1966 or 1967.

Details of the origin and number of clones, design, size and principal planting years of seed orchards are given in Tables 46–52. Table 45 gives a summary of acreage by species and ownership.

The present clonal seed orchards contain only *phenotypically* superior clones and after progeny testing those clones which show superior *general* or *specific* combining ability (*genotypically* superior clones) and have overlapping flowering times will be re-grafted to provide *elite* seed orchards for the production of certified seed. A programme for establishing *elite* orchards will begin sometime after 1966. The establishment of seedling seed orchards will continue for Lodgepole pine and every opportunity will be taken to utilise suitable progeny trials of all species for producing superior F_2 combinations.

Location of Seed Orchards

Brief details of the location, ownership, elevation, annual rainfall, soils, vegetation and isolation from contaminant pollen sources are given in columns 1, 2 and 3 of Tables 46–52. From these Tables it can be seen that the main acreage of Forestry Commission orchards has been established on arable or old pasture sites. Sites below 600 feet in the eastern or southern parts of Britain have been selected chiefly because of the generally drier, sunnier, warmer

Table 45

SUMMARY OF ACREAGES OF CLONAL AND SEEDLING ORCHARDS BY SPECIES AND OWNERSHIP AS AT MARCH 31ST, 1964

Species	Clonal Seed Orchards		Seedling Seed Orchards		Totals		
	Forestry Commission	Private	Forestry Commission	Private	Forestry Commission	Private	Grand Totals
Scots pine	81	12	—	—	81	12	93
Lodgepole pine	12½	—	—	—	12½	—	12½
European larch	1	1½	¼	—	1¼	1½	2¾
Japanese larch	3	—	¼	—	3¼	—	3¼
Hybrid larch (*L. X eurolepis*)	40	½	11	10¾	51	11¼	62¼
Douglas fir	17	½	3	—	20	½	20½
Western red cedar	5	—	—	—	5	—	5
Beech	5¼	—	—	—	5¼	—	5¼
Ash	¼	—	—	—	¼	—	¼
Total	165	14½	14½	10¾	179½	25¼	204¾

and less frosty conditions which are so vital in ensuring regular high yields of large well filled seeds. The risk of serious pollen contamination from undesirable sources has been minimised by keeping orchards as far away as possible from extensive plantations of the same species. Thus there are no main Scots pine orchards in north-east Scotland where Scots pine is the principal forest species. Where isolated and small (less than 5 acres) plantations of the same species do occur within 750 yards, the orchards have been planted to windward (insofar as the prevailing wind applies). In the Tables isolation has been described as excellent, very good, good, fair and poor. These terms can be interpreted as indicating no important pollen source within 2,000; 1,000; 750; 500 and 250 yards respectively.

Where Scots pine orchards have, through necessity, been planted in groups, for example at Ledmore, Perthshire and Archerfield, East Lothian, the orchards have been arranged in such a way that pollen drift between adjacent orchards is likely to be minimal. Even where inter-orchard pollination may occur it is unlikely to have any serious consequences since the orchards have been grouped so that neighbouring orchards are based on clones selected from adjacent or similar regions or estates. Orchards, plantations, or hedges of alternative species have occasionally been planted to provide pollen 'barriers' between orchards of the same species.

Site Preparation

Existing grass cover on the orchard sites has been accepted wherever suitable. Arable ground is usually ploughed and cultivated during the year prior to planting. A compound nitrogen, phosphorus and potassium fertiliser, at rates prescribed on the basis of a soil analysis, is applied and subsequently cultivated into the soil. A grass/clover seed mixture is sown either in early spring or autumn. Satisfactory seed mixtures are:—

Dry Sandy Sites—Rainfall 30 *ins. p.a.*	lbs./ac.	*Loams—Rainfall* 30 *ins.–*40 *ins. p.a.*	lbs./ac.
Creeping Red Fescue	22	Timothy S 50	12
New Zealand Browntop	8	Red Fescue S 59	6
Oregon Browntop	8	White Clover S 100	2
Ryegrass S 23	2	Wild White Clover S 184 *or* ..	
		Kent *or* English *or* ..	1
Kent Wild White Clover	2	Danish Pajbjerg I & V ..	
	42 lbs.		21 lbs.

Medium loam soils are normally subsoiled at a depth of 12 ins.–15 ins. before planting, by drawing a subsoiling tine along the planting lines and at right angles to the ground contours. Clay loams are treated more intensively by subsoiling at 6–7½ feet intervals across the area. Many fields already carry a system of tile drains which have often been renovated where necessary.

Planting positions are prepared, during the winter prior to planting, by digging a three-feet square patch to a depth of ten to twelve inches. At this time farmyard manure, hop waste or other organic manures if available, are incorporated through the soil. Planting is carried out during the months of January to March when weather and soil conditions are suitable.

If necessary, seed orchards are fenced against rabbits, hares and deer. Moles are trapped to prevent their 'spoil' heaps interfering with grass cutting.

Seed Orchard Management

Regular grass cutting is practised to maintain the level of the sward below 6–9 inches. Part of the cut grass is removed either for silage or hay, and part retained to provide a six-inch-deep mulch over a three-feet square area around the grafts until they are well established and over four-feet tall. Mid-season top-dressings of 'Nitrochalk' (21% N), at the rate of 2 ozs. per plant, are given during the early years until the plants are well established and growing vigorously.

Staking is unnecessary for pine grafts, but the crowns of Douglas fir and larch grafts often develop asymetrically, and frequently with a decided lean. This may be corrected by regular staking during the first two growing seasons. Light four feet long canes are used for this purpose, and the current annual growth is tied in a vertical position at three to four weekly intervals during the growing season. Staking is normally discontinued after two years. Grafts which do not respond to staking are pruned back to a strong bud situated well down on the main axis of the graft. It is essential that dominance of the shoot derived from this bud is maintained by repeated pruning back of any competitive side shoots over a two-year period.

Early and increased male flowering on larch may be achieved on grafts which are over ten feet tall by tying a proportion of the branches, arising some four to five feet above the ground, with their tips in downward pointing direction. This treatment is applied in March or April and ties are removed in the following autumn (Faulkner & Matthews 1961).

Pine, larch and Douglas fir grafts are frequently heavily attacked by aphids, *Adelges* spp., during the first ten years after planting. The severity of attack varies between clones and according to the season and vigour of the grafts. A high degree of control is obtained by timely and frequent sprays with a mixture consisting of three pints of 'Malathion 60' per 100 gallons of water to which an additional non-ionic wetting agent has been added. Tar-oil winter washes applied in February have also been used effectively against the aphid *Adelges viridis* on larch. Pine beetle, *Myelophilus piniperda*, and Pine shoot moth, *Evetria buoliana*, attacks on Scots pine grafts have been satisfactorily prevented by DDT sprays.

Seed Production

Scots pine clonal orchards produce regular crops of female flowers from the time of establishment onwards. In contrast male flowers have yet to be produced in quantity even in the ten-year-old orchards and it seems likely that worthwhile seed production will not begin until the orchards are at least twelve to fifteen years-old. Experiments to test the effects of crown pruning and fertiliser treatments as flowering stimulants are currently in progress. European larches, and Japanese larches, in particular, have produced heavy crops of both male and female flowers eight years after establishment, and beech begins to flower when six or seven years old. Douglas fir has produced only small quantities of male and female flowers after nine years.

Seedling seed orchards, except perhaps for the normally precocious Lodgepole pine, are likely to flower at a much later age than clonal seed orchards (Matthews 1955).

Seed yields are still speculative but evidence from Europe supports previous estimates for Scots pine at 10–15 lbs. per acre at fifteen years (Johnsson 1961). A minimum figure of 15–20 lbs. per acre for larches at the age of fifteen years seems likely to be realistic.

Seed Identification Numbers

The present Forestry Commission system of seed identification for imported seed, and seed collected from native stands or plantations, has been described by Matthews (1958). In essence the system consists of a bracketed coded two to four digit number (based on those described in the Universal Decimal Classification) which describes the continent, country, region, zone or county in which the source occurs. This number is prefixed firstly with the species in a standard abbreviated letter form and secondly with the last two digits of the Forest Year in which the cones or seeds ripen. e.g. SS 64(4123) is the code for Sitka spruce collected in autumn 1964 from Morayshire in Scotland. Seed sources of special merit are given a one or two-digit suffix number outside the brackets and those of especial research interest are given a three-digit suffix.

Seedling seed orchards containing progenies derived from open pollinated selected mother trees, from progenies derived from controlled crosses, or from sources of special provenance interest, are described according to the Universal Decimal Classification System. Research Branch Seed Identity suffix numbers have been given as a temporary measure to distinguish future plantations derived from *early* seed collections since these will vary genetically in consequence of various trees starting to flower in different years and as a result of improvement thinnings and other changes made on the evidence of provenance and progeny tests. Suffix numbers from 400 to 499, and 900 to 999 will be used in South England and Wales and North England and Scotland respectively. The suffix numbers are allocated in sequence of planting year for each species or hybrid orchard and are independent of the coded county number. Permanent Seed Identification Numbers will be allocated to each seedling orchard *after* all phenotypically inferior trees have been removed and the remaining trees are flowering regularly. This system is also used for second generation hybrid larch and hybrid larch backcross orchards.

Seed from *Clonal* seed orchards is identified by an Identity Number consisting of the species in standard abbreviated letter form, the crop year in which the cone or seed ripens, followed by (and within brackets) the seed orchard number prefixed with the letters 'NT' (symbolising 'Not Tested'), or 'A' (symbolising 'Approved'). The 'NT' prefix will only be replaced by the letter 'A' when all genotypically inferior clones have been removed and the remaining clones are flowering regularly, e.g. DF 64 (NT5) is Douglas fir seed collected from the untested Drumtochty orchard in 1964.

Hybrid larch orchards present certain difficulties since seed derived from both the European and Japanese larch parents will contain a proportion of both the pure species and the hybrid. In these orchards seed is collected *separately* from each species and the bracketed number is prefixed with 'E/HL' or 'J/HL' for the European and Japanese parents respectively, and the crop year. After raising in the nursery, plants of the true species are separated from the hybrids on the basis of visual characters and the appropriate prefix, e.g. 'EL', 'JL' or 'HL' is given to the plants. The bracketed seed orchard number remains unchanged. For this reason all clonal larch seed orchards have been numbered consecutively irrespective of the constituent species.

Clonal seed orchard numbers on which the Identity Number is based, and Research Branch Identity Numbers for seedling seed orchards, are given in column 4 of the Tables.

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TABLES OF SEED ORCHARDS

Table

SCOTS PINE

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Drumtochty Forest, Kincardineshire, Scotland. Expt. No. 7, P. 53. Forestry Commission.	56° 55′ N 2° 28′ W 450 ft. 33 ins.	Old walled garden. Heavy loam. Clover/grass sward. Good.
Ledmore Nursery, Perthshire, Scotland. Expt. No. 1, P. 56. Forestry Commission.	56° 28′ N 3° 32′ W 300 ft. 32 ins.	Pasture field. Heavy loam. Clover/grass sward. Good.
Bradon (Spye Park), Wiltshire, England. Bradon Expt. No. 4, P. 56. Forestry Commission.	51° 24′ N 2° 02′ W 350 ft. 30 ins.	Bracken land. Sandy loam. Grass/clover. Poor.
Aberlour House, Banffshire, Scotland. Private owner.	57° 29′ N 3°12′ W 400 ft. 34 ins.	Old walled garden. Medium loam. Grass. Fair.
Cullen Estate, Banffshire, Scotland. Private owner.	57° 21′ N 3° 36′ W 150 ft. 30 ins.	Old nursery. Sandy loam. Grass. Good.

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SEED ORCHARDS

Identity No. (4)	Origin of Clones (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
1	Altyre Estate, Morayshire.	7×7 Polycross	½ 1953–56
2	Crathes Estate, Kincardineshire.	7×7 Polycross	½ 1953–56
3	North Scotland mixture.	3×8 Top cross	½ 1953–56
4	Office Wood, Altyre Estate, Morayshire.	20×20 Polycross	2 1956–59
5	Carleith Wood, Crathes, Kincardineshire.	20×20 Polycross	2 1956–59
6	Castle Grant, Policy Woods, Morayshire.	20×20 Polycross	2 1956–59
7	Native Pinewood, Glentanar, Aberdeenshire.	20×20 Polycross	2 1956–59
8	Darnaway Estate, Morayshire.	20×20 Polycross	2 1956–59
9	Blelack and Woodend Estates, Aberdeenshire.	10×15 Polycross	¾ 1956–59
10	Cawdor Estates, Nairnshire.	10×10 Polycross	½ 1956–59
11	Tomb Wood, Rachan Estate, S. E. Scotland.	20×20 Polycross	2 1956–59
12	Charterhall and Mellerstain Estates, S.E. Scotland.	20×20 Polycross	2 1956–59
13	Minto, Eildon and Abbotsford Estates, S.E. Scotland.	20×20 Polycross	2 1956–59
14	Douglas, Shambellie, Wells and Hartrigge Estates, S. and S.E. Scotland.	20×20 Polycross	2 1956–59
15 (16)*	Altyre Estate, Morayshire.	20×10 Polycross	½ 1954–59
17	Strathspey	74×2	1 1964–66

*For I.N. 16, see pp. 222-223

Table 46—*continued*

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Castle Grant Estate, Grantown on Spey, Morayshire, Scotland. Private owner.	57° 21′ N 3° 36′ W. 750 ft. 30 ins.	Old walled garden. Sandy loam. Grass. Poor.
Glendye Estate, Kincardineshire, Scotland. Private owner.	56° 58′ N 2° 34′ W 900 ft. 35 ins.	Old pine woodland. Medium loam. Grass. Poor.
Walsham Forest (Bacton Wood), Norfolk, England. Expt. No. 2, P. 57. Forestry Commission.	52° 47′ N 1° 37′ E 50 ft. 26 ins.	Birch scrub. Medium loam. Grass. Very good.
Stenton Forest, Archerfield Section, East Lothian, Scotland. Expt. No. 3, P. 58. Forestry Commission.	56° 02′ N 2° 47′ W 10–25 ft. 25 ins.	Arable and pasture. Sand. Grass/clover or couch Good to very good.

SCOTS PINE

Identity No. (4)	Origin of Clones (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
16	Ten clones from the local Policy woods.	10×20 Polycross	½ 1958
18	Glendye (local), Kincardineshire.	10×20 Polycross	1½ 1959–60
19	*Loch Maree* (*Native*), Ross-shire.	10×17 Polycross	1 1957–58
20	*Native West Coast.* Loch Maree, Achnashellach, Shieldaig, Barrisdale, Coulin.	20×20 Polycross	2 1959–61
21	*Cultivated West Coast.* Inveraray, Aros, Eilean, Darrach, Gruline, Ardgour.	20×20 Polycross	2 1959–64
22	*Cultivated Argyll.* Invercoe, Awe, Auchnacloich, Glenure, Ardchattan, Fasnacloich, Inveraray, Carradale, Dunans, Tarbert, Ardkinglas, Benmore.	20×20 Polycross	2 1959–65
23	*Native Southern* (*Highlands*). Meggernie, Orchy, Rannoch, Blackmount.	20×20 Polycross	2 1960–61
24	*Cultivated E. Central.* Allean, Keltney, Meggernie, Edzell, Blair-Drummond, Rednocks, Lanrick, Tulloch, Strathyre, Auchlyne.	20×20 Polycross	2 1959–60
25	*Native Strathspey.* Rothiemurchus, Castle Grant.	20×20 Polycross	2 1960–61
26	*Cultivated Curr Wood X Ardverikie.* Castle Grant, Ardverikie, Moy.	20×20 Polycross	2 1959–60
27	*Cultivated Speyside.* Ballindalloch, Speymouth, Rosarie.	20×20 Polycross	2 1959–60

Table 46—*continued*

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Stenton Forest continued. *See* p. 222	*See* p. 222	*See* p. 222
Duns Forest (Oxendean), Berwickshire, Scotland. Expt. No. 1, P. 61. Forestry Commission.	55° 48′ N 2° 21′ W 500 ft. 32 ins.	Old pasture. Heavy loam to clay loam. Grass. Very good.
Keillour Forest, Perthshire, Scotland. Expt. No. 1, P. 63. Forestry Commission.	56° 24′ N 3° 42′ W 600 ft. 40 ins.	Old pasture. Medium loam. Grass. Very good.

Scots Pine

Identity No. (4)	Origin of Clones (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
28	*Cultivated Morayshire Coast.* Altyre, Logie.	20×20 Polycross	2 1959–60
29	*Cultivated Findhorn Valley.* Darnaway, Altyre, Dallas, Culbin.	20×20 Polycross	2 1959–60
30	*Cultivated Deeside.* Blelack, Crathes, Woodend.	20×20 Polycross	2 1959–60
31	*Native-Upper Deeside.* Glentanar, Mar, Ballochbuie.	20×20 Polycross	2 1959–60
32	*Cultivated Deeside.* Glentanar, Mar, Ballochbuie, Candacraig, Glendye.	20×20 Polycross	2 1959–60
33	*High Elevation-Deeside and Speyside.* Castle Grant, Dava, Rothiemurchus, Glentanar, Glenlivet.	20×20 Polycross	2 1959–60
34	*Cultivated South-West Scotland.* Shambellie, Knocknalling, Annandale, Earlston, Blackwood, Rammerscales, Glenapp, Langholm, Drumlanrig.	20×20 Polycross	2 1959–60
35	*Amat* (*Native*) Ross-shire.	10×10 Polycross	½ 1963
36	*Strathfarrar* (*Native*) Guisachan.	20×20 Polycross	2 1961–62
37	*Glen Affric* (Native)	20×20 Polycross	2 1962–63
38	*Northern Cultivated* Belladrum, Novar, Skibo, Dunrobin, Urquhart, Fairburn, Calrossie.	20×20 Polycross	2 1963
39	*Glengarry and Glenmoriston* Inverness-shire.	20×20 Polycross	2 1963
40	*Northern mixture of native and cultivated.* Maree, Achnashellach, Affric, Struy, Novar, Skibo, Guisachan, Eilean, Darrach, Amat, Glengarry, Fairburn.	20×20 Polycross	2 1963
41	*Northumbria.* Langley, Nunwick, Bolton, Hardcastle, Callaly, Healey, Redesmouth, Allendale, Alnwick.	30×30 Polycross	4½ 1963

Table 46—*continued*

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Alice Holt Forest (Plain Piece), Hampshire, England. Forestry Commission.	51° 11′ N 0° 51′ W 380 ft. 26 ins.	Old pasture. Clay loam with flints. Grass/clover. Isolation good.
Alice Holt Forest (Lodge Pond), Hampshire, England. Expt. No. 109, P. 60. Forestry Commission.	51° 11′ N 0° 51′ W 375 ft. 26 ins.	Derelict pasture. Clay loam. Grass. Fairly good.
Countesswells, Aberdeen, Scotland. Private owner.	57° 08′ N 2° 10′ W 300 ft. 30 ins.	Old arable. Medium loam. Grass. Fairly good.
Altyre Estate, Morayshire, Scotland. Private owner.	57° 35′ N 3° 39′ W 100 ft. 25 ins.	Old pasture. Sandy loam. Grass. Poor.
Minsteracres, Northumberland, England. Private owner.	54° 54′ N. 1° 58′ W 800 ft. 26 ins.	Old pasture. Clay loam. Grass. Good.
Alnwick Estate, Northumberland, England. Private owner.	55° 25′ N 1° 42′ W 150 ft. 35 ins.	Cleared woodland. Medium loam. Grass/clover. Very good.
Glentanar Estate, Aberdeenshire, Scotland. Private owner.	57° 03′ N 2° 52′ W 600 ft. 35 ins.	Old pasture. Sandy loam. Grass. Poor.
Castle Milk Estate, Dumfriesshire, Scotland. Private owner.	55° 04′ N 3° 19′ W 250 ft. 45 ins.	Pasture. Heavy loam. Grass. Good.

Scots Pine

Identity No. (4)	Origin of Clones (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
42	*English Mixture.*	20 × 20 Polycross	2 1965
43	*Brandon Park, Thetford.* East Anglia.	20 × 20 Polycross	2 1965
44	*East English Origin.*	20 × 20 Polycross	2 1965
45	*Wessex.* Surrey, Sussex, Hampshire, Wiltshire, Somerset.	20 × 20 Polycross	2 1965
46	*Surrey Heaths.* Windsor, Houndown, Minley, Hawley, Kingsmere, Bramshill.	20 × 20 Polycross	2 1962–63
47	*Scottish Mixture.* Darnaway, Altyre, Logie, Grant, Crathes, Glentanar, Rannoch, Keltney, Meggernie, Charterhall, Drumlanrig.	60 × 6 Polycross	2¾ 1958
48	Office Wood, Altyre Estate, Morayshire.	10 × 10 Polycross	½ 1959–61
49	N.E. and S.E. Scotland and N. England.	30 clones. various numbers Polycross	¼ 1963
50	Darnaway, Grant, Crathes, Altyre, Keltney.	10 × 10 Polycross	½ 1961
51	Glentanar, Aberdeenshire.	36 × 3 Polycross	¾ 1962
52	Drumlanrig, Shambellie, Blackwood. All in S.W. Scotland.	10 × 10 Polycross	½ 1962–63

Table 46—*continued*

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Newton Nursery, Morayshire, Scotland. Expt. No. 4, P. 60. Forestry Commission.	57° 40′ N 3° 25′ W 50 ft. 25 ins.	Arable. Clay loam. Grass/clover. Fair.
Whittingehame, East Lothian, Scotland. Expt. No. 4, P. 59. Forestry Commission.	55° 57′ N 2° 38′ W 350 ft. 28 ins.	Old walled garden. Medium loam. Grass/clover. Fair.
Lynn (Shouldham) (West Bilney), Norfolk, England. Expt. No. 3, P. 59. Forestry Commission.	52° 42′ N 0° 30′ E 50 ft. 26 ins.	Old pasture. Sandy loam. Grass/clover. Good.
Coull Estate, Aberdeenshire, Scotland. Private owner.	57° 06′ N 2° 48′ W 500 ft. 32 ins.	Old garden. Sandy loam. Grass. Poor.
Darnaway Estate, Morayshire, Scotland. Private owner.	57° 34′ N 3° 42′ W 220 ft. 27 ins.	Old pasture. Sandy loam. Grass. Poor.
Healey Estate, Northumberland, England. Private owner.	54° 55′ N 2° 00′ W 625 ft. 26 ins.	Old cricket field. Medium loam. Grass. Fair.
Abernethy, Inverness-shire, Scotland. Private owner.	57° 21′ N 3° 35′ W 800 ft. 35 ins.	Old nursery. Sandy loam. Grass. Poor.
Novar Estate, Ross-shire, Scotland. Private owner.	57° 40′ N 4° 18′ W 50 ft. 27 ins.	Derelict airfield. Medium loam. Grass. Fair.
Hirsel, Berwickshire, Scotland. Private owner.	55° 40′ N 2° 18′ W 150 ft. 26 ins.	Pasture. Loam. Grass. Good.
Nunwick Estate, Northumberland. England. Private owner.	55° 05′ N 2° 12′ W 320 ft. 26 ins.	Pasture field. Loam. Grass. Fair.

Scots Pine

Identity No. (4)	Origin of Clones (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
53	Boxholm (Sweden), Castle Grant, Scotland.	8×8 Polycross	½ 1960
54	*South Sweden.* Boxholm, Axfalls boda, Svärd Storpskogen.	10×5 Polycross	¼ 1959–61
55	Scottish mixture.	Random mixture of surplus Scottish ramets	3½ 1957–61
56	A mixture of clones mainly from Deeside.	Single ramets of each clone planted randomly.	¼ 1955–61
57	Darnaway.	10×12 Polycross	½ 1962
58	Healey.	10×10 Polycross	½ 1962
59	Abernethy (Native-Strathspey)	10×10 Polycross	½ 1959
60	Maree, Affric, Amat, Novar, Fairburn.	39 clones × 1 or 4 ramets	¼ 1962
61	Scottish mixture.	40 clones Various numbers Polycross	½ 1962
62	N.E. and S.E. Scotland and N. England.	28×1 or 2 ramets	¼ 1962

Table 46—*continued*

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Allendale (Bywell) Estate, Northumberland, England. Private owner.	54° 58′ N 1° 57′ W 400 ft. 25 ins.	Old pasture. Clay loam. Grass. Good.

Table

LODGEPOLE PINE

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Newton Nursery, Morayshire, Scotland. Expt. No. 1. P. 61. Forestry Commission.	57° 40′ N 3° 25′ W 50 ft. 25 ins.	Old forest nursery. Peaty sandy loam. Grass/clover. Excellent.
Wensum Forest (Walsham, Bacton Wood), Norfolk, England. Expt. No. 3, P. 62. Forestry Commission.	52° 47′ N 1° 37′ E 50 ft. 21 ins.	Scrub wasteland. Sandy loam. Grass. Excellent.
Lynn Forest (Shouldham), Norfolk, England. Expt. No. 5, P. 63. Forestry Commission.	52° 37′ N 0° 20′ E 50 ft. 28 ins.	Derelict pasture. Sandy loam. Grass. Excellent.
Keillour Forest, Perthshire, Scotland. Expt. No. 2, P. 64. Forestry Commission.	56° 24′ N 3° 42′ W 600 ft. 40 ins.	Old pasture. Medium loam. Grass. Excellent.

Scots Pine

Identity No. (4)	Origin of Clones (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
63	N.E. and S.E. Scotland and N. England.	28 clones, various numbers	¼ 1962

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Seed Orchards

Identity No. (4)	Origin of Clones (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
1	Culbin Forest (coastal origin) Morayshire.	10 × 10 Polycross	½ 1961
2	Plantations of coastal origins at Inchnacardoch, Wykeham, Achnashellach, Rendlesham and Dalbeattie forests.	20 × 30 Polycross	3 1962
3	Plantations of inland origin at Queen's, Inchnacardoch, Culbin, Wykeham, Loch Ard, Monaughty, Millbuie and Teindland forests.	28 × 30 Polycross	4¼ 1963
4	Coastal types from plantations in Eire.	64 × 15	4¾ 1964

Table

EUROPEAN LARCH

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Drumtochty Forest, (Glen Farquhar), Kincardineshire, Scotland. Expt. No. 8, P. 53. Forestry Commission.	56° 55′ N 2° 28′ W 560 ft. 34 ins.	Old walled garden. Medium loam. Grass/clover. Good.
Cawdor Estate, Nairnshire, Scotland. Private owner.	57° 32′ N 3° 55′ W 200 ft. 25 ins.	A clearing in mixed woodland. Sandy loam. Grass. Fair.
Alnwick Estate, Northumberland. England. Private owner.	55° 25′ N 1° 42′ W 150 ft. 35 ins.	Old walled garden. Medium loam. Grass clover sward. Very good.
Inveraray Estate, Argyllshire, Scotland. Private owner.	56° 14′ N 5° 06′ W 50 ft. 75 ins.	Old policy woodlands. Clay loam. Grass sward. Isolation good.
Dean Forest (Clanna), Gloucestershire England. Expt. No. 78. P. 59. Forestry Commission.	51° 44′ N 2° 37′ W 300 ft. 35 ins.	Derelict bracken/grassland. Medium loam. Grass/herbs. Poor.

Table

JAPANESE LARCH

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Newton Nursery. (Ramie Park), Morayshire, Scotland. Expt. No. 4, P. 57. Forestry Commission.	57° 40′ N 3° 25′ W 50 ft. 25 ins.	Old pasture. Clay cap over sandy sub-soil. Grass. Fairly good.
Dean Forest (Clanna), Gloucestershire. England. Expt. No. 78, P. 59. Forestry Commission.	51° 44′ N 2° 37′ W 300 ft. 35 ins.	Derelict bracken/ grassland. Medium loam. Grass herb. Poor.

48

SEED ORCHARDS

Identity No. (4)	Origin of Clones or Seedlings (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
2	All from Scotland.	15×10 Polycross	1 1953
13	Five clones from Cawdor policy woods and five from The Ord Wood, Cawdor Estate.	10×10 Polycross	½ 1959/60
14	Mixed English and Scottish.	24 clones with 1 to 14 ramets of each Random mixture	½ 1961
15	Inveraray estate.	10×10 Polycross	½ 1961
(4238)405	Mixture of seedlings from Newton Seed Orchard 9.P.52 and B1 12 yr. Sudeten, Poland.	Mixed seedlings (57 plants of 14 origins)	¼ 1959

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SEED ORCHARDS

Identity No. (4)	Origin of Clones or Seedlings (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
7	19 Scottish clones and 1 Danish.	20×20 Polycross	3 1957
(4238)407	Mixture of seedlings from Newton seed orchards. Tree Bank Expt. 9. P. 52.	Progeny trial (160 plants of 33 crosses)	¼ 1959

Table

HYBRID LARCH

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Birkhill Estate, Fife, Scotland. Private owner.	56° 24′ N 3° 05′ W 150 ft. 26 ins.	Old woodland. Sandy loam. Woodland vegetation. Fair.
Newton Nursery, Morayshire, Scotland. Expt. No. 9. P. 52. Forestry Commission.	57° 40′ N 3° 25′ W 50 ft. 25 ins.	Old forest nursery. Sandy loam, clay cap in places. Grass/clover. Good.
Grizedale Forest (Hallwood), Lancashire, England. Expt. No. 4, P. 53. Forestry Commission.	54° 20′ N 3° 2′ W 400 ft. 70 ins.	Cleared woodland. Medium loam. Forest grasses. Good.
Mabie Forest, Dumfriesshire, Scotland. Expt. No. 4, P. 53. Forestry Commission.	55° 2′ N 3° 38′ W 100 ft. 42 ins.	Old walled garden and fruit orchard. Clay loam. Grass/clover. Poor.
Whittingehame, East Lothian, Scotland. Expt. No. 2, P. 56. Forestry Commission.	55° 57′ N 2° 38′ W 350 ft. 28 ins.	Old arable farmland. Clay loam. Grass/clover. Excellent.
Bradon (Spye Park), Wiltshire, England. Expt. No. 10, P. 56. Forestry Commission.	51° 24′ N 2° 02′ W 350 ft. 30 ins.	Bracken land. Sandy loam. Grass/clover. Poor.
Newton Nursery, Morayshire, Scotland. Expt. No. 1, P. 58. Forestry Commission.	57° 40′ N 3° 25′ W 50 ft. 25 ins.	Forest nursery. Medium loam. Grass/clover. Good.
Alice Holt Forest (Lodge Pond), Hampshire, England. Expt. No. 85, P. 59. Forestry Commission.	51° 11′ N 0° 5′ W 380 ft. 26 ins.	Old pasture. Clay loam with flints. Grass/clover. Fair.

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SEED ORCHARDS

Identity No. (4)	Origin of Clones or Seedlings (5)	No. of Clones Design (7)	Area (Acres) Planting Yrs. (8)
(4128)1	Seedlings from selected European larch parents at Cawdor and Birkhill. Hybrid larch seedlings from Dunkeld parents, and back cross hybrids from Birkhill.	A collection of 12 seedling seed orchards.	½ to 1½ acres each. Total 9 acres. 1931–1955
1	Scottish and English.	3 European × 12 Japanese topcross.	4 1952
4	5 European larches from Grizedale. 4 Japanese larches from Glendye. 1 Japanese larch from Cardross.	10 × approx. 20 Polycross	1 1953
3	European larches from Scotland and Northern England. Japanese larches from Scotland.	12 European larches. 12 Japanese larches. Top cross	2 1953
5	30 Scottish European larches. 30 Scottish Japanese larches.	60×20 Polycross	10 1956/9
6			1 1956
8	30 European larches from Britain. 28 Japanese larches from Britain. 2 Japanese larches from Denmark.	60×20 Polycross	3 1958
9	23 Scottish European larches. 7 English European larches. 24 Scottish Japanese larches. 6 English Japanese larches.	60 × approx. 40 Polycross	8 1959

Table 50—*continued*

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Dean Forest (Clanna), Gloucestershire, England. Expt. No. 78, P. 59. Forestry Commission.	51° 44′ N 2° 37′ W 300 ft. 35 ins.	Derelict bracken/ grassland. Medium loam. Woodland grasses.
Countesswells, Aberdeenshire, Scotland. Private.	57° 08′ N 2° 10′ W 300 ft. 30 ins.	Old arable fields. Medium loam. Grass. Very good.
Alnwick Estate, Northumberland, England. Private.	55° 25′ N 1° 42′ W 150 ft. 35 ins.	Cleared woodland. Medium loam. Grass/clover. Very good.
Newton Nursery (Gravel Hole), Morayshire, Scotland. Expt. No. 1. P. 60. Forestry Commission.	57° 40′ N 3° 25′ W 50 ft. 25 ins.	Old pasture. Sandy loam, peaty pockets. Grass. Good.
Alice Holt Forest, Hampshire, England. Expt. No. 97. P. 60. Forestry Commission.	51° 11′ N 0° 5′ W 380 ft. 26 ins.	Old pasture. Clay loam with flints. Grass/clover. Fair.

HYBRID LARCH SEED ORCHARDS

Identity No. (4)	Origin of Clones or Seedlings (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
(4238)401	Seedlings Newton Seed Orchard and Tree Bank. Expt. 9.P.52.	All hybrid plants 20 plants each of 30 crosses.	1½ 1959
(4238)404	Seedlings. Newton Seed Orchard and Tree Bank. Expt. 9.P.52.	All hybrid plants 20 plants each of 30 crosses.	1½ 1959
(4238)406	Seedlings Newton Seed Orchard and Tree Bank. Expt. 9.P.52.	All hybrid plants 359 plants from 81 crosses.	2 1959
(4238)402	Seedlings Newton Seed Orchard and Tree Bank. Expt. 9.P.52.	Mixed hybrid and Japanese plants (alternate) 20 plants each of 60 crosses.	3 1959
(4238)403	Newton 9.P52, British and Polish stands.	Mixed hybrid and European plants (Alternate) 20 plants each of 45 origins.	3 1959
(4124)900	Seedlings. Various hybrids both natural and from controlled pollinations from Newton 9.P.52 and European larch from Almost Plus stand EL 56(4123)3 Carron Estate, Banffshire, Scotland.	Mixed hybrid and European plants Polycross	1¾ 1959
12	5 Scottish European larches. 4 Scottish Japanese larches. 1 English Japanese larch.	10×10 Polycross	½ 195
10	20 European larches from Britain. 19 Japanese larches from Britain. 1 Japanese larch from Denmark.	40×80 Polycross	8 1960
11	18 Scottish European larches. 12 English European larches. 9 Scottish Japanese larches. 15 English Japanese larches. 5 Irish Japanese larches. 1 Danish Japanese larch.	60×7 Polycross	3 1960

Table
DOUGLAS FIR

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Drumtochty Forest, Kincardineshire, Scotland. Expt. No. 7. P. 53. Forestry Commission.	56° 55′ N 2° 28′ W 450 ft. 33 ins.	Old walled garden. Heavy loam. Grass/clover. Very good.
Ledmore Nursery, Perthshire, Scotland. Expt. No. 2. P. 56. Forestry Commission.	56° 28′ N 3° 32′ W 300 ft. 32 ins.	Pasture field. Heavy loam. Grass/clover. Very good.
Whittingehame, East Lothian, Scotland. Expt. No. 3. P. 56. Forestry Commission.	55° 57′ N 2° 38′ W 350 ft. 28 ins.	Old arable farmland. Grass/clover. Clay loam. Good.
Dean Forest (Clanna), Gloucestershire, England. Expt. No. 79. P. 59. Forestry Commission.	51° 44′ N 2° 37′ W 300 ft. 35 ins.	Derelict bracken/ grassland. Medium loam. Woodland grasses. Fair.
Alnwick Estate, Northumberland, England. Private.	55° 25′ N 1° 42′ W 150 ft. 35 ins.	Old walled garden. Medium loam soil. Grass/clover. Good.
Grizedale Forest (Tinklers), Lancashire, England. Expt. No. 6. P. 60. Forestry Commission.	54° 23′ N 3° 02′ W 400 ft. 35 ins.	Bracken/grass field. Medium loam. Grass. Fair.
Alice Holt Forest (Lodge Pond), Hampshire, England. Expt. No. 95. P. 60. Forestry Commission.	51° 11′ N 0° 51′ W 375 ft. 26 ins.	Derelict pasture. Clay loam. Grass. Fair.
Alice Holt Forest (Plain Piece), Hampshire, England. Expt. No. 112. P. 61. Forestry Commission.	51° 11′ N 0° 51′ W 375 ft. 26 ins.	Derelict pasture. Clay loam. Grass. Fair.

51
SEED ORCHARDS

Identity No. (4)	Origin of Clones or Seedlings (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
5	East Scotland.		½ 1953
6	A collection of seven orchards each containing 10 clones from Scone, Perthshire; Scone and Strathallan, Perthshire; Touch, Stirlingshire; Murthly, Perthshire; Lanrick, Perthshire; Inveraray, Argyllshire; Dawyck, Peeblesshire; Benmore, Argyllshire and a miscellaneous collection of clones from Duncraig, Barcaldine, Dunans and Stonefield.	Each a 10×10 Polycross	4 1956
7	Scotland.	30×13 (or 14) Polycross	3 1956/60
4	South-west England.	48×17 (or 18) Polycross	2½ 1959
8	Alnwick and Cragside estates, Northumberland.	10×10 Polycross	½ 1959
9	Scotland, England and Wales.	A random mixture of 53 clones with from 1 to 10 ramets of each.	1½ 1960/63
1	Scotland and England.	30×10 Polycross	1½ 1960
2	Scotland and England.	21 clones Topcross	2 1961/64

TABLE 51—*continued*

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
Andover Forest (Doles Wood), Hampshire, England. Expt. No. 2. P. 64. Forestry Commission.	51° 16′ N 1° 29′ W 450 ft. 26 ins.	Old woodland. Clay loam with flints. Bramble/grass. Birch cover. Good.
Duns Forest (Oxendean), Berwickshire, Scotland. Expt. No. 2. P. 61.	55° 24′ N 2° 21′ W 500 ft. 32 ins.	Old pasture. Heavy clay loam soil. Grass. Very good.

Table

SEED ORCHARDS—

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
WESTERN RED CEDAR Alice Holt Forest (Lodge Pond), Hampshire, England. Expt. No. 84. P. 59. Forestry Commission.	51° 11′ N 0° 51′ W 375 ft. 26 ins.	Derelict pasture. Clay loam. Grass. Excellent.
Ledmore Nursery, Perthshire, Scotland. Expt. No. 3. P. 59. Forestry Commission.	56° 28′ N 3° 32′ W 300 ft. 32 ins.	
Dean Forest (Clanna), Gloucestershire, England. Expt. No. 77. P. 59 and 90. P. 64. Forestry Commission.	51° 44′ N 2° 37′ W 300 ft. 35 ins.	Derelict bracken/grassland. Medium loam. Woodland grasses. Good.
Faskally Forest, Perthshire, Scotland. Expt. No. 1. P. 62. Forestry Commission.	56° 43′ N 3° 46′ W 375 ft. 33 ins.	Old walled garden. Medium loam. Grass/clover. Very good.
BEECH Alice Holt Forest (Lodge Pond), Expt. No. 94. P. 60. Forestry Commission.	51° 11′ N 0° 51′ W 375 ft. 26 ins.	Old nursery. Clay loam with flints. Grass. Excellent.

DOUGLAS FIR SEED ORCHARDS

Identity No. (4)	Origin of Clones or Seedlings (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
3	Scotland and England.	20 clones 4×9 and 8×10 and 8×8 Polycross	1½
(4145)900	Twenty-five seedling progenies based on six mother and eighteen father trees.	Random mixture of seedlings.	3½ 1961/2

52
MISCELLANEOUS SPECIES

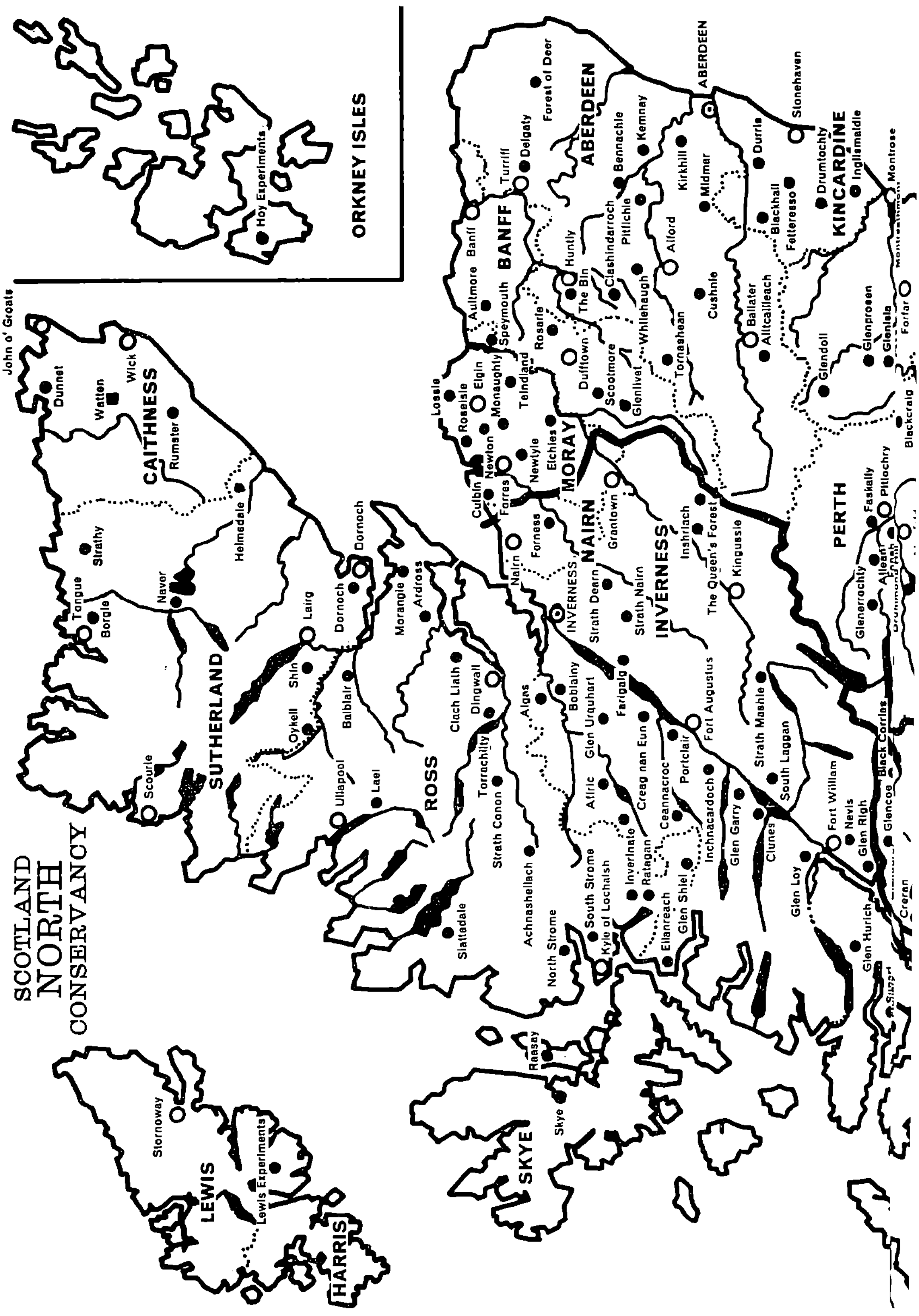
Identity No. (4)	Origin of Clones or Seedlings (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
1	England and Scotland.	20×9 Polycross clonal trial (combined)	½ 1959
2	England and Scotland.	20 clones clonal trial (combined)	½ 1959
3	England and Scotland.		3 1959/61
4	England and Scotland.	14×15 Polycross	1 1962
5	Kingscote Estate, Gloucestershire.	20 grafts of 7 clones 10 grafts of 6 clones.	1 1960

TABLE 52—*continued*

Location, Experiment No., Ownership (1)	Latitude, Longitude, Elevation, Rainfall (2)	Previous Land Use, Soil, Ground Cover, Isolation (3)
BEECH—continued Hemsted Forest, Kent, England. Expt. No. 1. P. 56. Forestry Commission.	 51° 05′ N 0° 36′ E 300 ft. 30 ins.	 Old nursery. Heavy loam. Tumble down grass. Excellent.
Hemsted Forest, Kent, England. Expt. No. 6. P. 57. Forestry Commission.	51° 05′ N 0° 36′ E 300 ft. 30 ins.	Old nursery. Heavy loam. Tumble down grass. Excellent.
Hemsted Forest, Kent, England. Expt. No. 9. P. 60. Forestry Commission.	51° 05′ N 0° 36′ E 300 ft. 30 ins.	Old nursery. Heavy loam. Tumble down grass. Excellent.
Whittingehame, East Lothian, Scotland. Expt. No. 1. P. 56. Forestry Commission.	55° 57′ N 2° 38′ W 350 ft. 28 ins.	Old walled garden site. Medium loam soil. Grass/clover sward. Established 1955. Fairly good.
ASH Hemsted Forest, Kent, England. Expt. No. 4. P. 56. Forestry Commission.	 51° 05′ N 0° 36′ E 300 ft. 30 ins.	 Old nursery. Heavy loam. Tumble down grass Fair.

Seed Orchards—Miscellaneous Species

Identity No. (4)	Origin of Clones or Seedlings (5)	No. of Clones Design (6)	Area (Acres) Planting Yrs. (7)
2	Slindon, Sussex.	2 separate 10×10 Polycross	$1\frac{1}{2}$ 1956
3	Scotland and England.	10×10 Polycross	$\frac{3}{4}$ 1956
4	English	3×14 1×13 1×15 Polycross	$\frac{1}{2}$ 1960
1	Scotland and England.	10×10 Polycross	1 1956/59
1	Garnons, Herefordshire.	4×12 2×20 Top cross	$\frac{1}{4}$ 1956



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Dunnet
Watten
Wick
CAITHNESS
Rumster
Strathy
Helmsdale
Tongue
Borgie
Naver
SUTHERLAND
Lairg
Dornoch
Shin
Oykell
Balblair
Scourie
Ullapool
Lael
Morangie
Ardross
ROSS
Clach Liath
Dingwall
Torrachilty
Strath Conon
Achnashellach
Slattadale
North Strome
South Strome
Kyle of Lochalsh
LEWIS
Stornoway
Lewis Experiments
HARRIS
SKYE
Skye
Raasay
Inverinate
Ratagan
Ellanreach
Glen Shiel
Affric
Glen Urquhart
Creag nan Eun
Ceannacroc
Portclair
Inchnacardoch
Fort Augustus
Farigaig
Boblainy
Aigas
INVERNESS
Strath Dearn
Strath Nairn
Inshriach
The Queen's Forest
Kingussie
Glen Garry
Clunes
Strath Mashie
South Laggan
Fort William
Nevis
Glen Righ
Glencoe
Black Corries
Glen Loy
Glen Hurich
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Tornashean
Huntly
The Bin
Clashindarroch
Pitfichie
Whitehaugh
Alford
Cushnie
Turriff
Delgaty
Forest of Deer
ABERDEEN
Bennachie
Kemnay
Kirkhill
Midmar
ABERDEEN
Durris
Stonehaven
Blackhall
Fetteresso
Drumtochty
Inglismaldie
KINCARDINE
Montrose
Ballater
Alltcailleach
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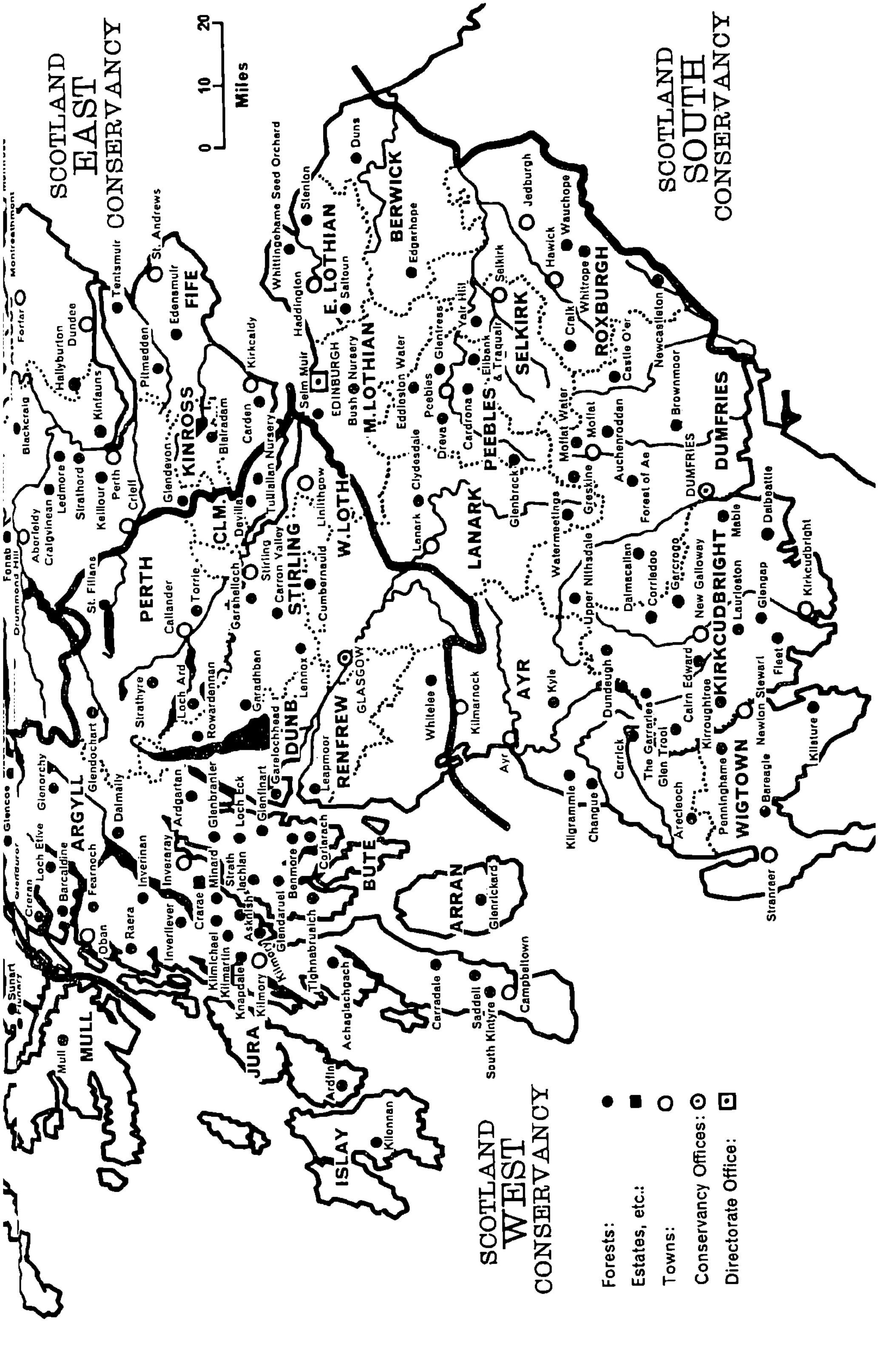
Glenisla
Forfar
Blackcraig
PERTH
Faskally
Pitlochry
Allean
Glenerrochty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PEEBLES
LANARK
DUMFRIES
KIRKCUDBRIGHT
WIGTOWN
AYR
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MULL
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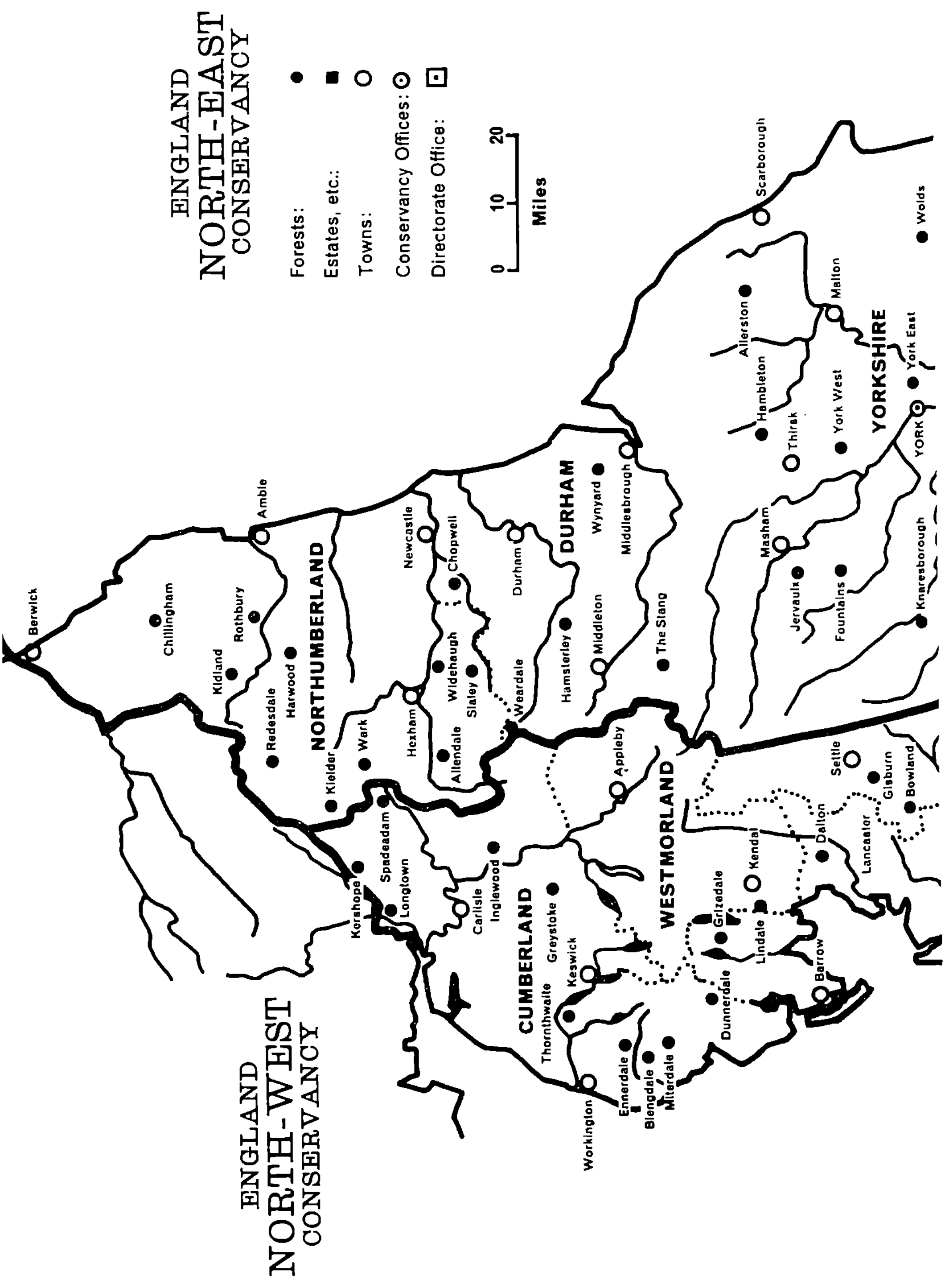
EDINBURGH
GLASGOW
DUMFRIES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Slaley
Wideheugh
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Chopwell
Durham
Weardale
Hamsterley
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Wynyard
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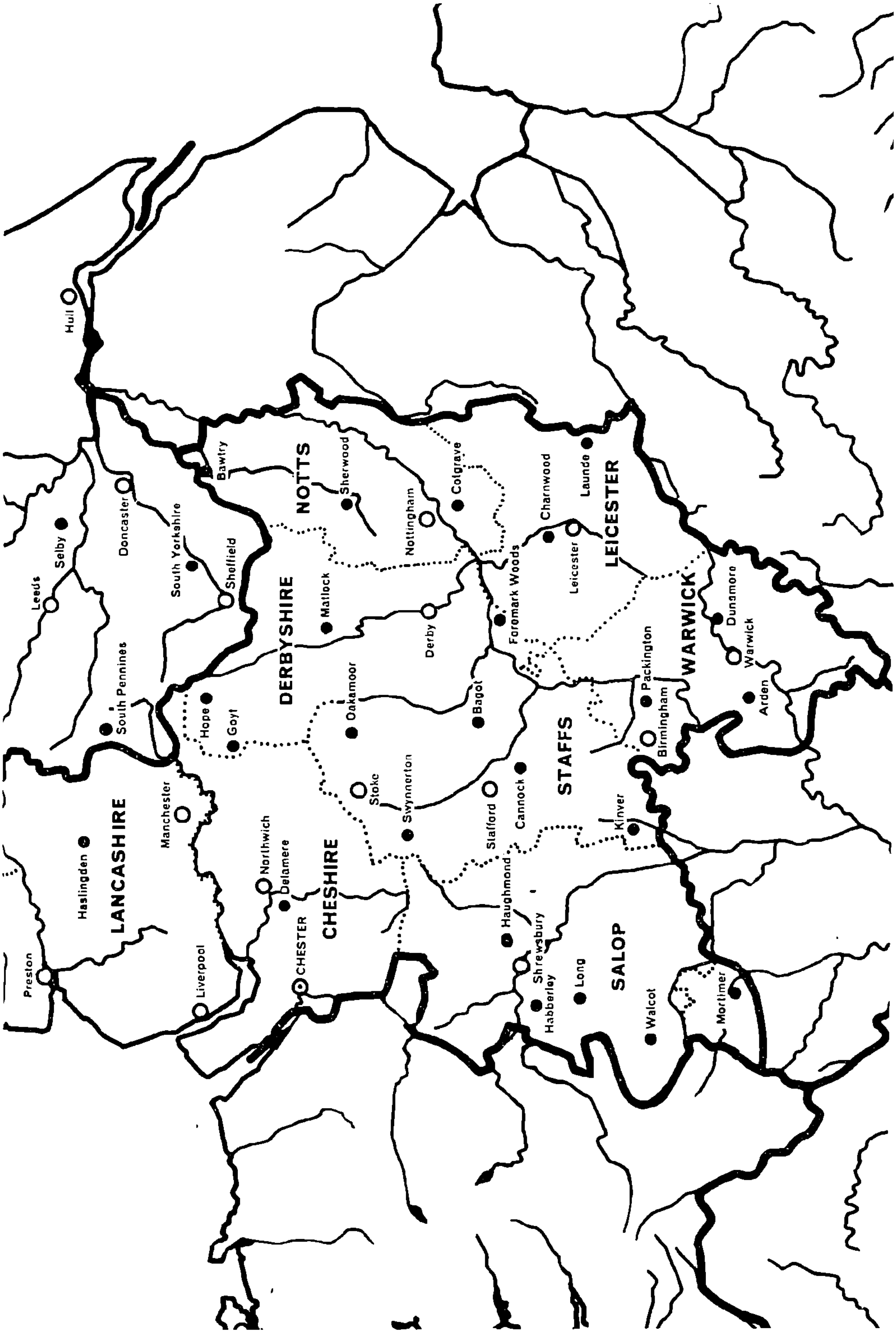
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Leicester
Faromark Woods
DERBYSHIRE
Matlock
Derby
South Pennines
Hope
Goyt
Oakamoor
Bagot
Packington
WARWICK
Dunsmore
Warwick
Arden
Birmingham
STAFFS
Cannock
Stafford
Stoke
Swynnerton
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LANCASHIRE
Haslingden
Manchester
Northwich
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SALOP
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Walcot
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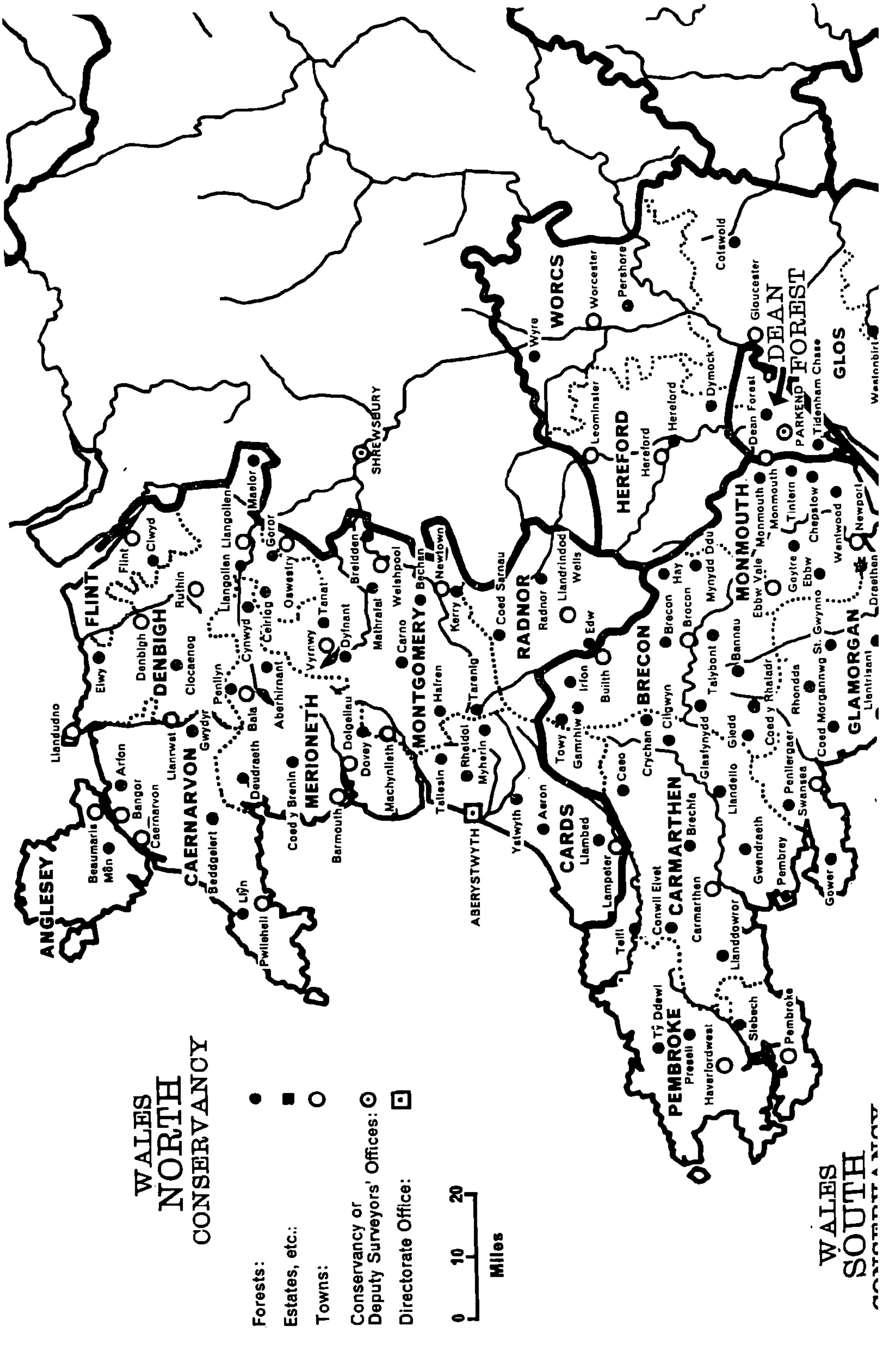
Preston
Liverpool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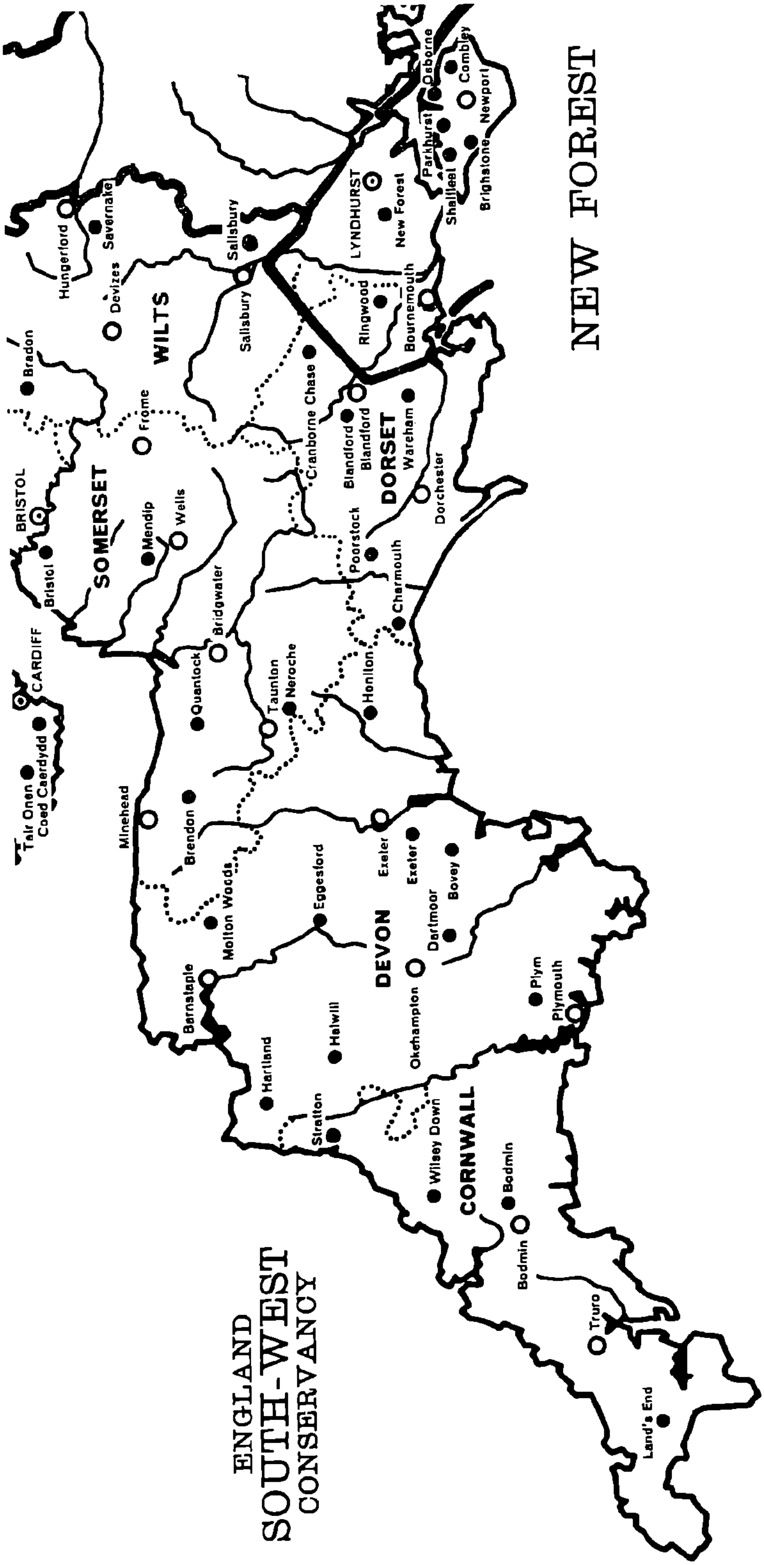
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Savernake
Devizes
Salisbury
Bradon
Frome
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Mendip
Wells
Bridgwater
Quantock
Taunton
Neroche
Coed Caerdydd
Tair Onen
Minehead
Brendon
Molton Woods
Eggesford
Exeter
Bovey
Dartmoor
Okehampton
Barnstaple
Hartland
Halwill
Stratton
Wilsey Down
Bodmin
Truro
Land's End
Plym
Plymouth
Honiton
Charmouth
Poorstock
Dorchester
Wareham
Blandford
Cranborne Chase
Ringwood
Bournemouth
New Forest
Shalfleet
Brighstone
Parkhurst
Newport
Osborne
Combley


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The King's Forest
Thetford
Thetford Chase
Swaffham
Lynn
King's Lynn
CAMBS
Burwell
Willingham
Bardney
LINCOLNSHIRE
Kesteven
Laughton
Lincoln
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Rockingham
Rockingham
HUNTS
Huntingdon
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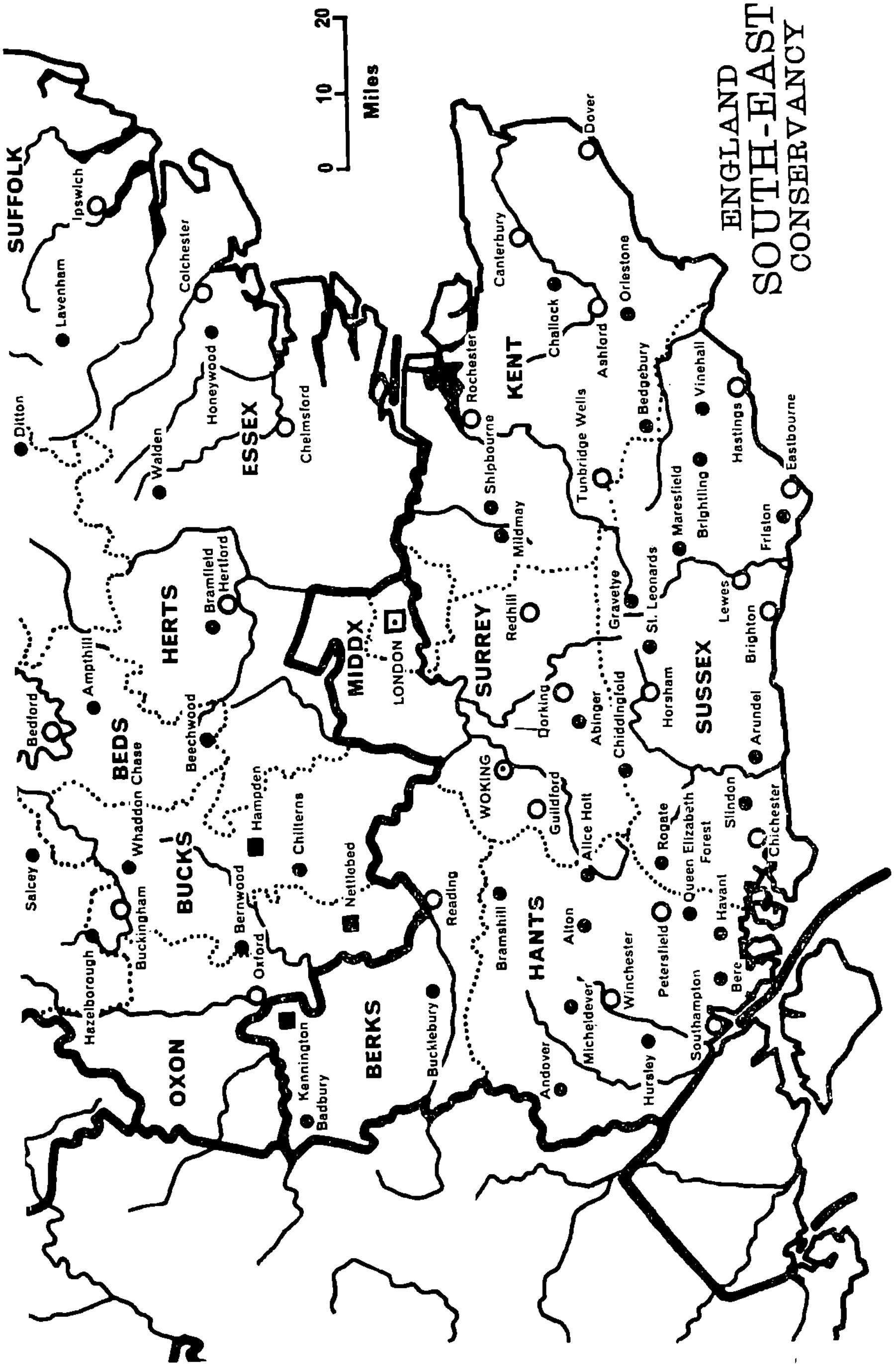
NORTHANTS
Northampton
Yardley Chase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Chelmsford
Walden
Dover
Canterbury
Orlestone
Challock
Ashford
KENT
Rochester
Shipbourne
Tunbridge Wells
Bedgebury
Vinehall
Hastings
Eastbourne
Mildmay
Maresfield
Brightling
Friston
HERTS
Bramfield
Hertford
MIDDX
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Redhill
Gravetye
St. Leonards
Lewes
Brighton
SUSSEX
Horsham
Chiddingfold
Abinger
Dorking
Ampthill
Bedford
BEDS
Whaddon Chase
Beechwood
WOKING
Guildford
Alice Holt
Rogate
Queen Elizabeth Forest
Slindon
Chichester
Arundel
Salcey
BUCKS
Hampden
Chilterns
Buckingham
Bernwood
Nettlebed
Reading
Bramshill
Alton
HANTS
Petersfield
Havant
Oxford
Hazelborough
Winchester
Micheldever
Bere
Southampton
OXON
Kennington
BERKS
Bucklebury
Badbury
Andover
Hursley

APPENDIX I

Main Experimental Projects and Localities

The list is not comprehensive. It is a preliminary guide to those who may wish to see experimental work on any particular subject or subjects. The omission of a subject from the list does not mean that no work on it has been done, as some important projects are omitted because experimental work on them is not yet informative. The forests or estates concerned are shown on the maps on pages 244–251.

NURSERY EXPERIMENTS

Benmore Nursery, near Dunoon (Argyll)
Bramshill Nursery (Hampshire)
Bush Nursery, near Edinburgh
Fleet Nursery, Gatehouse of Fleet (Kirkcudbright)
Inchnacardoch Nursery, near Fort Augustus (Inverness)
Kennington Nursery, near Oxford
Newton Nursery, near Elgin (Moray)
Sugar Hill Nursery, Wareham Forest (Dorset)
Tulliallan Nursery, near Alloa (Fife)

AFFORESTATION EXPERIMENTS ON PEAT

Achnashellach Forest (Wester Ross)
Beddgelert Forest (Caernarvon)
Inchnacardoch Forest (Inverness)
Kielder Forest (Northumberland)
Naver Forest (Sutherland)
Strathy Forest (Sutherland)
Watten (Caithness) in conjunction with Department of Agriculture and Fisheries for Scotland
Wauchope Forest (Roxburgh)

AFFORESTATION EXPERIMENTS ON HEATHLAND

Allerston Forest, Harwood Dale (Yorkshire)
Allerston Forest, Wykeham and Broxa (Yorkshire)
Inshriach Forest (Inverness)
Land's End Forest, Croft Pascoe (Cornwall)
Millbuie Forest (Ross)
Taliesin Forest (Cardigan)
Teindland Forest (Moray)
Wareham Forest (Dorset)

FOREST NUTRITION

Allerston Forest, Broxa (Yorkshire)
Culbin Forest (Moray)
Exeter Forest (Devon)
Inchnacardoch Forest (Inverness)
Tarenig Forest (Cardigan)
Teindland Forest (Moray)
Wareham Forest (Dorset)
Wilsey Down Forest (Cornwall)

SOIL MOISTURE STUDIES

Aldewood Forest (Suffolk)
Bramshill Forest (Hampshire)
Inchnacardoch Forest (Inverness)
New Forest (Hampshire)

PROVENANCE EXPERIMENTS

Scots pine:	Findon Forest (Easter Ross) Thetford Chase (Norfolk)
Lodgepole pine:	Achnashellach Forest (Wester Ross) Allerston Forest, Wykeham (Yorkshire) Ceiriog Forest (Denbigh) Clocaenog Forest (Denbigh) Forest of Deer (Aberdeen) Millbuie Forest (Easter Ross) Taliesin Forest (Cardigan)
European larch:	Coed y Brenin (Merioneth) Mortimer Forest (Herefordshire) Savernake Forest (Wiltshire)
European and Japanese larches:	Clashindarroch Forest (Aberdeen) Drummond Hill Forest (Perth) Fetteresso Forest (Kincardine) Lael Forest (Wester Ross)
Douglas fir:	Glentress Forest (Peebles) Land's End Forest, St. Clement (Cornwall) Lynn Forest, Shouldham (Norfolk) Mortimer Forest (Shropshire)
Norway and Sitka spruces:	Newcastleton Forest (Roxburgh) The Bin Forest (Aberdeen)
Sitka spruce:	Clocaenog Forest (Denbigh) Glendaruel Forest (Argyll) Kielder Forest (Northumberland) Mynydd Ddu Forest (Monmouth) Radnor Forest (Radnor) Ratagan Forest (Wester Ross) Taliesin Forest (Cardigan) Wark Forest (Northumberland) Wilsey Down Forest (Cornwall)
Western hemlock:	Brecon Forest (Brecon) Brendon Forest (Somerset) Clocaenog Forest (Denbigh) New Forest (Hampshire) Rheidol Forest (Cardigan) Thetford Chase (Norfolk) Wareham Forest (Dorset)
Western Red cedar:	Alice Holt Forest (Hampshire) New Forest (Hampshire) Radnor Forest (Radnor) Thetford Chase (Norfolk)
Beech:	Queen Elizabeth Forest (Hampshire) Savernake Forest (Wiltshire)

CONVERSION OF COPPICE

Alice Holt Forest, Marelands (Hampshire)
Cranborne Chase (Dorset)
Forest of Dean, Penyard and Flaxley (Herefordshire and Gloucestershire)

PLANTING EXPERIMENTS ON CHALK DOWNLANDS

Friston Forest (Sussex)
Queen Elizabeth Forest (Hampshire)

ESTABLISHMENT OF OAK

Dymock Forest (Gloucestershire and Hereford)
Forest of Dean (Gloucestershire and Hereford)

DRAINAGE EXPERIMENTS

Bernwood Forest (Oxford and Buckinghamshire)
Forest of Ae (Dumfries)
Halwill Forest (Devon)
Kielder Forest (Northumberland)
Loch Ard Forest, Flanders Moss (Stirling)
Orlestone Forest (Kent)

POPLAR TRIALS AND SILVICULTURAL EXPERIMENTS

Bedgebury Forest (Kent)
Blandford Forest (Dorset)
Cannock Chase (Staffordshire)
Creran Forest (Argyll)
Doncaster Forest (Yorkshire)
Dyfnant Forest (Montgomery)
Forest of Dean (Gloucestershire)
Lynn Forest, Gaywood (Norfolk)
Quantock Forest (Somerset)
Rogate Forest (Hampshire)
Stenton Forest (East Lothian)
Wentwood Forest (Monmouthshire)
Wynyard Forest (Durham)
Yardley Chase (Bedfordshire and Northamptonshire)

ARBORETA

National Pinetum, Bedgebury (Kent)
Westonbirt Arboretum (Gloucestershire)
Whittingehame (East Lothian)

MAJOR COLLECTIONS OF SPECIES PLOTS

Crarae (Argyll)
Kilmun, Benmore Forest (Argyll)
Bedgebury (Kent)
Brechfa Forest (Carmarthen)
Thetford Chase (Norfolk and Suffolk)

SPECIES COMPARISONS IN RELATION TO SPECIAL SITES

Achnashellach (Wester Ross)
Aldewood Forest (Suffolk)
Beddgelert Forest (Caernarvon)
Bodmin Forest (Cornwall)
Brendon Forest (Somerset)
Brownmoor (Dumfries)
Caeo Forest (Carmarthen)
Cairn Edward Forest (Kirkcudbright)
Clashindarroch (Aberdeen)
Coed Morgannwg (Glamorgan)
Dovey Forest (Merioneth and Montgomery)
Forest of Ae (Dumfries)
Forest of Dean (Gloucestershire)
Garadhban (Stirling)
Glentress Forest (Peebles)
Glentrool (Kirkcudbright)
Glen Urquhart Forest (Inverness)
Gwydyr Forest (Carnarvon)
Inchnacardoch Forest (Inverness)
Kielder Forest (Northumberland)
Land's End Forest (Cornwall)
Micheldever Forest (Hampshire)
Mynydd Ddu (Brecon and Monmouth)

New Forest (Hampshire)
Pembrey Forest (Carmarthen)
Rockingham Forest (Northamptonshire)
Rosedale, Allerston Forest (Yorkshire)
Teindland Forest (Moray)
Thetford Chase (Norfolk)
Tintern Forest (Monmouth)
Wareham Forest (Dorset)
Wykeham, Allerston Forest (Yorkshire)

RE-AFFORESTATION EXPERIMENTS

Forest of Ae (Dumfries)
Kielder Forest (Northumberland)
Lennox Forest (Stirling)
Newcastleton Forest (Roxburgh)
Thetford Chase (Norfolk and Suffolk)
Michaelston, Coed Morgannwg (Glamorgan)

MENSURATION

The following are experiments in which permanent sample plots are used as assessment units and which are of interest for growth and yield studies. Replicated experiments are marked with an asterisk (*).

SPACING

Scots pine:	Thetford Chase (Suffolk and Norfolk) Roseisle Forest (Moray) Tintern Forest (Monmouthshire) Ebbw Forest (Monmouthshire)
Corsican pine:	Aldewood Forest (Suffolk)
European larch:	Mortimer Forest (Hereford) Forest of Dean (Gloucestershire) Radnor Forest (Radnor) Fleet Forest (Kirkcudbright)
Japanese larch:	Bodmin Forest (Cornwall) Dalbeattie Forest (Kirkcudbright) Drumtochty Forest (Kincardine) Rheola, Coed Morgannwg (Glamorgan) Crychan Forest (Brecon) Ebbw Forest (Glamorgan) Caeo Forest (Carmarthen) Brechfa Forest (Carmarthen)
Norway spruce:	Monaughty Forest (Moray) Clocaenog Forest (Denbigh, Merioneth) Kerry Forest (Montgomery) Rheola, Coed Morgannwg (Glamorgan)
Sitka spruce:	Allerston Forest (Yorkshire) Brecon Forest (Brecon) Rheola, Coed Morgannwg (Glamorgan) Gwydyr Forest (Caernarvon) Clocaenog Forest (Denbigh, Merioneth)
Douglas fir:	Allerston Forest (Yorkshire) Ystwyth Forest (Cardigan) Brechfa Forest (Carmarthen)

THINNING

Scots pine:	Aldewood Forest (Suffolk) Thetford Chase (Suffolk and Norfolk) Swaffham Forest (Norfolk)

	New Forest (Hampshire) Cannock Chase (Staffordshire) Edensmuir Forest (Fife)* Speymouth Forest (Moray and Banff)
Corsican pine:	Aldewood Forest (Suffolk) Thetford Chase (Suffolk and Norfolk) Swaffham Forest (Norfolk) New Forest (Hampshire) Culbin Forest (Moray) Pembrey Forest (Carmarthen)
European larch:	Forest of Dean (Gloucestershire) Murthly Estate (Perthshire)
Japanese larch:	Bodmin Forest (Cornwall) Stourhead Estate (Wiltshire) Glentress Forest (Peebles) Drumtochty Forest (Kincardine) Brechfa Forest (Carmarthen) Rheola Forest (Glamorgan)
Norway spruce:	Kershope Forest (Cumberland) Bowmont Forest (Duke of Roxburgh)* Bennan Forest (Kirkcudbright) Elgin (Moray) Tintern Forest (Monmouth)
Sitka spruce:	Brendon Forest (Somerset) Forest of Ae (Dumfries) Ardgartan Forest (Argyll) Loch Eck Forest (Argyll)*
Picea omorica:	Bedgebury Forest (Kent)
Douglas fir:	Wensum Forest (Norfolk) Alice Holt (Hampshire)* Glentress Forest (Peebles) Mynydd Ddu (Brecon, Monmouth) Gwydyr Forest (Caernarvon)
Noble fir:	Dovey forest (Merioneth, Montgomery)
Beech:	Nettlebed Estate (Buckinghamshire) Hampden Estate (Buckinghamshire)
Oak:	Micheldever Forest (Hampshire) Forest of Dean (Gloucestershire) Wensum Forest (Norfolk) Hazelborough Forest (Northamptonshire)

UNDERPLANTING

European larch underplanted with various species:	Dymock Forest (Gloucestershire) Haldon Forest (Devon)

MIXTURES

Oak/larch:	Tintern Forest (Monmouth)
Sitka spruce/Japanese larch *Sitka spruce/Lodgepole pine*	Beddgelert Forest (Caernarvon)

GENETICS

PROPAGATION CENTRES

Alice Holt (Hampshire)
Bush Nursery (near Edinburgh)
Grizedale Nursery (Lancashire)

TREE BANKS

Alice Holt (Hampshire)
Bush Nursery (near Edinburgh)
Newton Nursery (Moray)

SEED ORCHARDS

Alice Holt (Hampshire)
Bradon Forest (Wiltshire)
Drumtochty Forest (Kincardine)
Forest of Dean (Gloucestershire)
Keillour Forest (Perthshire)
Ledmore Forest (Perthshire)
Lynn Forest (Norfolk)
Newton Nursery (Moray)
Stenton Forest (East Lothian)

PROGENY TRIALS

Alice Holt Forest (Hampshire)
Clocaenog Forest (Denbigh)
Chillingham Forest (Northumberland)
Chilterns Forest (Buckinghamshire)
Coed y Brenin Forest (Merioneth)
Devilla Forest (Fife and Clackmannan)
Farigaig Forest (Inverness)
Forest of Dean (Gloucestershire)
Glenlivet Forest (Banffshire)
Gwydyr Forest (Caernarvon)
Kilmichael Forest (Argyll)
Kilmory Forest (Argyll)
Saltoun Forest (East Lothian)
Stenton Forest (East Lothian)
Teindland Forest (Moray)

TREATMENT OF SEED STANDS

Culbin Forest (Moray and Nairn)
Thetford Chase (Norfolk and Suffolk)

PATHOLOGICAL RESEARCH AREAS

ELM DISEASE TRIALS

Huntingdon Forest, Ettisley Wood (Huntingdonshire)
Kesteven Forest (Lincolnshire and Rutland)
The King's Forest (Suffolk)

TOP DYING OF NORWAY SPRUCE

Knapdale Forest (Argyll)

FOMES ANNOSUS

Clocaenog Forest (Denbigh)
Kerry Forest (Montgomery)
Lael Forest (Ross)
The Bin Forest (Aberdeen)
Thetford Chase (Norfolk and Suffolk)

BACTERIAL CANKER OF POPLAR

Aldewood Forest, Fen Row Nursery (Suffolk)
Lynn Forest, Gaywood Nursery (Norfolk)
Thetford Chase, Mundford Nursery (Norfolk)

KEITHIA THUJINA TRIALS ON WESTERN RED CEDAR

Alice Holt Forest (Hampshire)
Ringwood Nursery (Dorset)
Sugar Hill Nursery, Wareham Forest (Dorset)

PINE CANKER: CRUMENULA SORORIA

Ringwood Forest (Hampshire and Dorset)

ENTOMOLOGY

PINE LOOPER MOTH: BUPALUS PINIARIUS

Cannock Chase (Staffordshire)
Culbin Forest (Moray and Nairn)

LARCH SAWFLY: ANOPLONYX DESTRUCTOR

Drumtochty Forest (Kincardine)
Mortimer Forest (Hereford and Shropshire)

SPRUCE APHID: NEOMYZAPHIS ABIETINA

Alice Holt Forest (Hampshire)
Bramshill Forest (Hampshire)
Dovey Forest (Merioneth and Montgomery)
Forest of Ae (Dumfries)
Inverliever Forest (Argyll)
New Forest (Hampshire)

DOUGLAS FIR SEED WASP: MEGASTIGMUS SPERMOTROPHUS

Brendon Forest (Somerset)
Culloden Forest (Inverness)
Mortimer Forest (Herefordshire)
New Forest (Hampshire)
Thetford Chase (Norfolk)
Thornthwaite Forest (Cumberland)

APPENDIX II

Staff Engaged in Research and Development

As at 31st March, 1964

The staff listed here are engaged wholly or in part in research and development. Where not indicated otherwise, staff belong to the Directorate of Research. For convenience, staff attached to certain sections belonging to the Headquarters organisation are included, since part of their activities are considered research or development, and these are recorded in Reports on Forest Research.

An asterisk (*) indicates an Assistant Forester.

FOREST RESEARCH STATION: Alice Holt Lodge, Wrecclesham, Farnham, Surrey.
Tel. Bentley 2255

A. Watt, C.B.E., B.A.	Director
R. F. Wood, B.A., B.Sc.	Conservator
T. D. H. Morris	Senior Executive Officer
Miss O. A. Harman	Clerical Officer (Director's Secretary)

SILVICULTURE (SOUTH)

R. M. G. Semple, B.Sc., Head of Section	District Officer
J. M. B. Brown, B.Sc., Dip.For.	District Officer (Ecologist)
J. R. Aldhous, B.A.	District Officer
M. Nimmo	District Officer
A. I. Fraser, B.Sc.	District Officer
J. Jobling, B.Sc.	District Officer

Office:

C. Ridley	Executive Officer
A. Taggart	Clerical Officer
D. T. Baker	Clerical Assistant
Miss E. Burnaby	Scientific Assistant

Research Foresters: Alice Holt

R. Hendrie (Head Forester, South-east Region)
P. W. W. Daborn, A. J. A. Graver*, A. Sibbick*, A. C. Hansford*, P. J. Mobbs*, A. C. Swinburn*

Special duties: J. B. H. Gardiner (Wind studies)
R. W. Genever (Utilization)
B. C. Howland (Ecology)

Research Foresters: Outstationed

Regions and Areas		*Centre*
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APPENDIX III

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